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METHOD OF THE CONTROLLED CURRENT REGULATION –MICROLATEROLOG

METODA KONTROLOVANÉ REGULACE PROUDU – MIKROLATEROLOG

František Ryšavý [1]

Abstract

In this paper there is described theory of Microlalerolog on the base of theory of the controlled current regulation. The fundamental characteristics, the coefficient of focusing and the main constant of the electrode array, are depending on partial constants. These can be exactly calculated with the help of the exactly-derived formulas. The shape of the electrode array can be circular, elliptical or squared. The much stretched oblong/elliptical array, with two or more electrodes, is called Proximity Log or Micro Spherically Focused Log (MSFL). It is discussed too problem of eliminating the electrode potentials of the electrode surface

Abstrakt

Tato práce popisuje teorii Mikrolaterologu na bázi teorie kontrolované regulace proudu. Základní charakteristiky, jako jsou koeficient fokusace a hlavní konstanta uspořádání elektrod, závisejí na dílčích konstantách. Ty se dají přesně spočítat na základě přesně odvozených vzorců. Elektrodové uspořádání může mít kruhový, eliptický nebo čtvercový tvar. Velmi prodloužené obdélníkové/eliptické uspořádání, které používá dvě nebo více elektrod, se nazývá Proximity Log nebo systém MSFL. Diskutuje se také problém odstranění elektrodových potenciálů z povrchu elektrod.

Keywords

circular array, elliptical array, coefficient of focusing, the main constant, partial constants, microlaterolog, well-logging

Klíčová slova

kruhové uspořádání, eliptické uspořádání, koeficient fokusace, hlavní konstanta, dílčí konstanty, Mikrolaterolog, karotáž

1 Introduction

This paper presents description of complete system of Microlaterolog with the help of mathematical formulas. Through mathematics describes its various electrode systems. The mathematical formulas were derived before; all were published mainly in EGRSE (2016) and EGRSE (2017). It is in RYŠAVÝ (2016) and RYŠAVÝ (2017). In this paper are only published the derived final formulas. They are both for circular and elliptical electrodes, because both electrodes systems are manufactured and used for measurement. The number of electrodes in the electrode array play significant role too. We distinguish systems with two, four and five electrodes; in case of elliptical electrode systems there exist stretched electrode systems presenting Proximity Log having different number of electrodes. The last mentioned systems are yet close to orthogonal electrodes systems as MSFL – Micro Spherically Focused Log and next are.

The published mathematical formulas are large enough; however, make able to count two important characteristics for Microlaterolog: the main constant of the electrode array denoted as K and the coefficient of focusing that is denoted as η. Both characteristics are counted after before derived formulas through partial characteristics denoted as k_{AM}, k_{AN}, k_{BM}, k_{BN}, further, k_{EM} and k_{EN}. Just these partial characteristics use the large mathematical formulas here published. For counting they need to have some input data. The data present geometric characteristics of the electrode array as the diameter of the feeding electrode, the diameter of the inner circle of annulus for potential/current electrodes, and too width of annulus for potential/current electrodes, are. Counting of the partial constants is made one by one. These input characteristics are always easy measurable; each geophysicist has a length gauge.

The paper offers to create universal software system of counting of the basic characteristics of Microlaterolog denoted as K and η. It would be through the partial characteristics. As input data for counting it would be geometric characteristics of the electrode system in numeric form. The software system would ask at first whether it is circular or elliptical electrodes, and further, how many electrodes are there. Then the system would ask for input geometric data of the electrode system in numeric form. It would do for each of all partial characteristics. As the last the software system would present on the screen the main constant K and the coefficient of focusing η.

You can suppose that such software system each geophysicist ought to have in his notebook. It could him help very greatly. In case of replacement of the electrode pad or for controlling of the electrode array the geophysicist, working in the field conditions, would not look for the water tank, for salt and for precise gauge of water resistivity, to control the main constant of the electrode array. All these requisites needed up to now for controlling with the way of modelling would go out. By pushing of the only button on his notebook the geophysicist would have in two seconds the asked numeric value of the main constant K. And it would be data all exact, because this characteristic is just determined only and only by geometry of the electrode array. Any faults evoked by modelling are not there. It is worth considering about that and too to take the published large mathematical formulas as important for facilitation of work in the hard field conditions.

I think that theoretical papers ought to carry results being useable for practice. It ought not to be “science for science”; it ought to be “science for practice”. On other hand it is not possible to empty such work; to clear away all mathematical formulas or at least a part of them. Figures and text description cannot be sufficient, mainly when it is the theoretical work offering material for creating the all new software system that can significantly help to geophysicists working in hard field conditions. As regards relation of Microlaterolog to Laterolog there is a lot common. System of the controlled current regulation both named methods brings them closer together.

For theory of Microlaterolog it holds the same what was said about theory of Laterolog. The only difference are the derived formulas of partial constants remarked as k_{AM}, k_{AN}, k_{BM}, k_{BN}, further, k_{EM} and k_{EN}. The electrode array is always concentric; its shape is usually circular, however, it can be elliptical, as well; in last time as orthogonal too. Theory of Microlaterolog is well explainable with the help of theory of the controlled current regulation. This was published by MARUŠIAK (1968) and MARUŠIAK, TĚŽKÝ and JONÁŠOVÁ (1969). The above theory is a higher degree of more general theory making possible to analyse various electric well-logging methods based on focusing of the electric current; in this case it is Microlaterolog. Next papers needed for formulas used are: RYŠAVÝ (2013), RYŠAVÝ (2016) and too RYŠAVÝ (2017). Chapter 12 is a follow-up to work RYŠAVÝ (2006).

2 Theory of Microlaterolog

The electrode array was said to be concentric. It has either circular shape, or elliptic one. The metallic electrodes are on the insulator pad which is pressed on the wall of borehole. This pad copies all bulges being on the surface of the borehole wall. The pad can be formed like ellipsis or a rounded oblong. It needs to have the pad its dimensions adequately big, because the electrical surroundings out of pad affect registering. The electrodes should be segmented into parts to be neglected an effect of the electrode potentials, too.

The electrode array is characterized by two important characteristics. The first is the coefficient of focusing denoted as η. This can be positive or negative. The negative one is not acceptable, because such focusing forces the current lines to flow parallelly to the borehole wall. The positive one, on the contrary, is highly acceptable, because the current lines are directed perpendicularly to the borehole wall.

The second characteristic is the main constant of the electrode array remarked as K. This characteristic can be only positive. If it is negative, it will be caused with an error of calculation.

Both the above characteristics are consisted of partial constants denoted as k_{AM}, k_{AN}, k_{BM}, k_{BN}, further, k_{EM} and k_{EN}. These have all different formulas than it was for Laterolog. In this paper there are distinguished the partial constants for the 5-electrode Microlaterolog denoted also like Pseudo-Microlaterolog having elliptical or circular electrode arrays, further, the 4-electrode Microlaterolog known as Classical Microlaterolog which has again elliptical or circular electrode arrays, and finally, the 2-electrode Microlaterolog, when both electrodes are simultaneously the current and potential ones and can have again elliptical or circular electrode arrays. Special array called Proximity Log can be presented with the 2-electrode elliptical Microlaterolog having elongated the big half-axis, whereas, the small half-axis is extraordinary small. In the recent time such electrode array has a rectangular shape.

Condition of regulation is that $U_N = U_M$ and we regulate with the help of electrodes E and E_0 serving like the guard electrodes. The second possible condition of regulation is $U_N = 0$; it is less acceptable way because electric current lines stream parallelly to the borehole wall. In such case you register voltage being between M and N electrodes. If you regulate so that the voltage difference being between electrodes M and N is zero, $U_N = U_M$, you will record the voltage between electrodes M and N_0 located on the surface of earth. The detailed explanation of theory of the controlled current regulation was published in MARUŠIAK (1968) and MARUŠIAK, TĚŽKÝ and JONÁŠOVÁ (1969); the next explanation is in RYŠAVÝ (2013).

The last mentioned author presents there formula of SCHLUMBERGER (1989), *Log Interpretation Principles /Applications*. The formula looks like this:

$$U_M = \frac{R_t \times I_A}{K} \times \left\{ 1 + \frac{R_i}{R_m} + \frac{R_s}{R_m} + \frac{R_t}{R_m} \right\}^{-1}, \quad (1)$$

The formula adjusted for resistivity has the following form:

$$R = K \times \frac{U_M}{I_A} = R_t \times \left\{ 1 + \frac{R_i}{R_m} + \frac{R_s}{R_m} + \frac{R_t}{R_m} \right\}^{-1}, \quad (2)$$

where R_m = the mud resistivity [Ωm],

R_s = the resistivity of adjacent beds [Ωm],

R_i = the resistivity of invasion zone [Ωm], and

R_t = the resistivity of non-invaded bed [Ωm].

This holds for rock and tool surrounded by highly conductive mud. If you have a pad with electrodes that firmly contacts the borehole wall, it will be all different position. The characteristic R_t is missing and instead of that you have characteristic R_i . As well there is no characteristic R_m . Function of this takes over characteristic R_{x_0} . Relation (2) can be copied like that:

$$R = K \times \frac{U_M}{I_A} = R_i \times \left\{ 1 + \frac{R_s}{R_{x_0}} + \frac{R_i}{R_{x_0}} \right\}^{-1}, \quad (3)$$

where R_{x_0} = the resistivity of flushed zone [Ωm].

For condition $U_N = U_M$ it presents that $R_{x_0} \to \infty$; current contours flow perpendicularly to the borehole wall.

$$R = K \times \frac{U_M}{I_A} = \lim_{R_{x0} \to \infty} R_i \times \left\{ 1 + \frac{R_s}{R_{x0}} + \frac{R_i}{R_{x0}} \right\}^{-1} \approx R_i \quad \text{for } U_N = U_M \text{. It is about resistivity of invasion zone.} \quad (4)$$

If it is condition $U_N = 0$ then holds that $R_{x_0} \to 0$; current contours flow parallelly to the borehole wall.

$$R = K \times \frac{U_M}{I_A} = \lim_{R_{x_0} \to 0} R_i \times \left\{ 1 + \frac{R_s}{R_{x_0}} + \frac{R_i}{R_{x_0}} \right\}^{-1} \approx \frac{R_{x_0}}{1 + \left(\frac{R_s}{R_i} \right)} \approx \begin{cases} R_{x_0} & \text{for } U_N = 0 \text{ and } R_i >> R_s \\ 0 & \text{for } U_N = 0 \text{ and } R_i << R_s \end{cases} \quad (5)$$

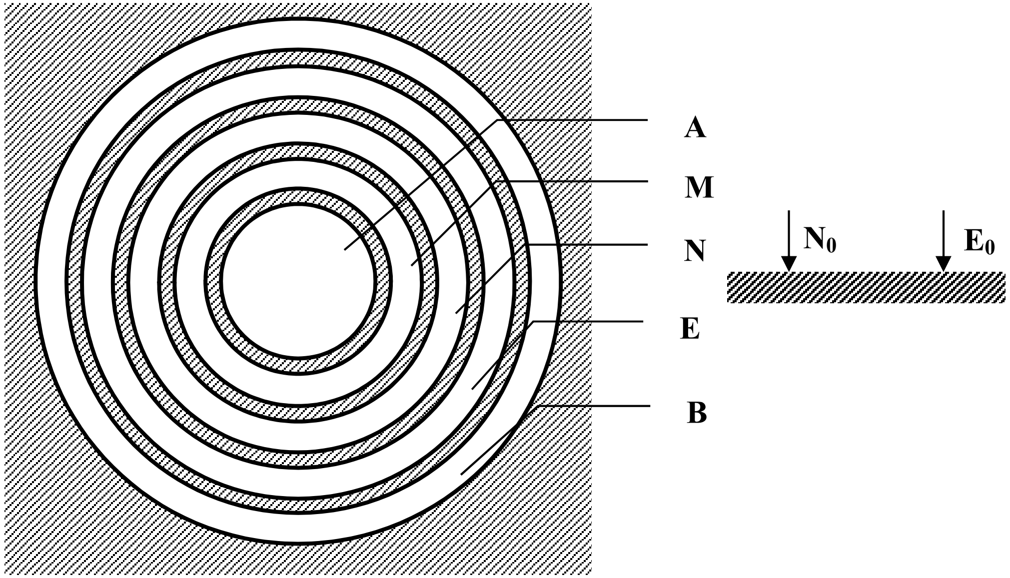


Fig.1 The 5-electrode Microlaterolog denoted like Pseudo-Microlaterolog – the electrode array

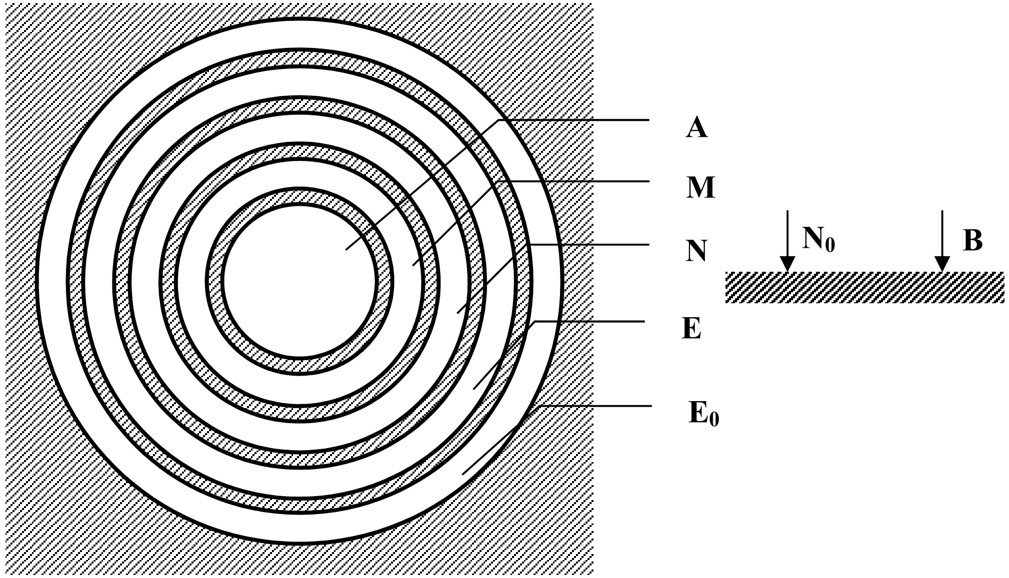


Fig.2 The 5-electrode Microlaterolog denoted like Microlaterolog – the electrode array

In this case when you register R_{x_0} and $R_i >> R_s$ is, it can be in the sand-shale borehole section very oft. In contrary, when you register zero and $R_i << R_s$ is, it presents saturated thin sandy beds between carbonates, joint systems in carbonates or mylonite zones. Joints and mylonites can be too in volcanic and metamorphic rocks. As for condition $U_N = 0$ the current contours flow parallelly to the borehole wall the horizontal cracks are perpendicular to them. Similarly it is with the angular cracks which are almost perpendicular. It presents excellent conditions for their location. However, the first variance of focusing, $U_N = U_M$ is more demanded. The recorded value in most cases tends to the resistivity of invasion zone. If you need to record the resistivity of flushed zone or to solute special geological tasks in carbonates then you take the second variance of focusing or to use electrode array for the first variance with 5 electrodes on the pad.

Here is one another thing; it touches of the electrode array. If on the pad there are both feeding electrodes A and B one speaks about **Pseudo-Microlaterolog**. If electrode B is out of pad then it is **Microlaterolog**.

3 The 5-electrode Microlaterolog with circular electrode array

3.1 Pseudo-Microlaterolog – regulation on condition $U_N = U_M$

The coefficient of focusing is known like this, RYŠAVÝ (2013):

$$\eta = \left(\frac{k_{AN}^{-1} - k_{AM}^{-1}}{k_{EM}^{-1} - k_{EN}^{-1}} \right) + \left(\frac{k_{BM}^{-1} - k_{BN}^{-1}}{k_{EM}^{-1} - k_{EN}^{-1}} \right). \tag{6}$$

The main constant of the electrode array is after this equation:

$$K = \left\{ \left(k_{AM}^{-1} - k_{BM}^{-1} \right) + k_{EM}^{-1} \times \eta \right\}^{-1}. \tag{7}$$

Resistivity of rocks is described with formula:

$$R = K \times \frac{U_M}{I_A}, \tag{8}$$

where R = the resistivity of rocks [Ωm],

U_M = the voltage being on electrode M [mV], and

I_A = the feeding current streaming through electrodes A and B [mA].

For calculation of partial constants k_{AM} and k_{AN}, RYŠAVÝ (2017), it holds that:

$$\left(\frac{k}{d} \right) = \frac{2\pi}{F}, \text{ and} \tag{9}$$

$$F = 8 \times \left(\frac{2}{\pi} \right) \times \left[\mathrm{E}\left\{ \frac{D}{d} \right\} - \left(1 + \frac{2H}{d} \right)^{-1} \times \mathrm{E}\left\{ \left(\frac{D}{d} \right) \times \left(1 + \frac{2H}{d} \right)^{-1} \right\} \right] \text{ for } D < d. \tag{10}$$

where D = diameter of the feeding electrode A [m],

d = diameter of the inner circle of annulus for electrodes M/N [m],

H = width of annulus for electrodes M/N [m], and

E { } = elliptical integral of the second kind.

The partial constants k_{EM} and k_{EN} further constants k_{BM} and k_{BN}, RYŠAVÝ (2017), too, are directed with the following relations:

$$\left(\frac{k}{D} \right) = \frac{2\pi}{F_1 + F_2}, \tag{11}$$

$$F_1 = +6 \times \left(\frac{2L}{D} + 1 \right)^{-1} \times \frac{\left(\frac{2H}{D} + \frac{d}{D} \right)}{\left(\frac{2H}{D} + 2 \times \frac{d}{D} \right)} \times \left[\left(\frac{\frac{2H}{D} + \frac{d}{D}}{\frac{2L}{D} + 1} + 1 \right) \times \mathrm{Argsinh}\left\{ \left(\frac{\frac{2H}{D} + \frac{d}{D}}{\frac{2L}{D} + 1} + 1 \right)^{-1} \right\} - \left(\frac{\frac{2H}{D} + \frac{d}{D}}{\frac{2L}{D} + 1} - 1 \right) \times \mathrm{Argsinh}\left\{ \left(\frac{\frac{2H}{D} + \frac{d}{D}}{\frac{2L}{D} + 1} - 1 \right)^{-1} \right\} \right], \tag{12}$$

$$F_2 = -6\times\left(\frac{2L}{D}+1\right)^{-1}\times\frac{\left(\frac{2H}{D}+\frac{d}{D}\right)}{\left(\frac{2H}{D}+2\times\frac{d}{D}\right)}\times\left[\left(\frac{2H}{D}+\frac{d}{D}+1\right)\times \text{Argsinh}\left\{\left(\frac{2H}{D}+\frac{d}{D}+1\right)^{-1}\right\}-\left(\frac{2H}{D}+\frac{d}{D}-1\right)\times \text{Argsinh}\left\{\left(\frac{2H}{D}+\frac{d}{D}-1\right)^{-1}\right\}\right]. \quad \text{for } D < d. \tag{13}$$

where D = diameter of the inner circle of annulus for potential electrodes M/N [m],
L = width of annulus for potential electrodes M/N [m],
d = diameter of the inner circle of annulus for current electrodes E/B [m], and
H = width of annulus for current electrodes E/B [m].

Due to published formulas we are able to enumerate characteristics K and η. This type of Microlaterolog called Pseudo-Microlaterolog is depicted in the fig.1. Just this electrode array thanks to electrode B on the pad is very convenient for registering characteristic R_{x_0} what is resistivity of flushed zone. All other electrode arrays measure more resistivity of invasion zone R_i or resistivity somewhere in between R_{x_0} and R_i; depends on the depth of penetration.

3.2 Pseudo-Microlaterolog – regulation on condition $U_N = 0$

After RYŠAVÝ (2013) coefficient of focusing will be negative and its form derived is as follows:

$$\eta = -k_{EN}\times\left(k_{AN}^{-1}-k_{BN}^{-1}\right). \tag{14}$$

The main constant of array is this:

$$K = \left\{\left(k_{AM}^{-1}-k_{BM}^{-1}\right)+k_{EM}^{-1}\times\eta\right\}^{-1} = \left\{\left(k_{AM}^{-1}-k_{BM}^{-1}\right)-\frac{k_{EN}}{k_{EM}}\times\left(k_{AN}^{-1}-k_{BN}^{-1}\right)\right\}^{-1}. \tag{15}$$

Resistivity of rocks is described with formula (8). The partial constants are same like it was in the previous chapter. They are directed with formulas from (9) up to (13). The electrode array is same like it is in the fig.1, however, focusing is different. On condition that $U_N = U_M$ you register voltage being between electrodes M and N_0, whereas, when it is condition $U_N = 0$ one register voltage between electrodes M and N. You measure characteristic R_{x_0} very reliably.

3.3 Microlaterolog – regulation on condition $U_N = U_M$

The difference is evident if you compare fig.1 to fig.2. Here are both guard electrodes E and E_0 on the pad and electrode B is in the infinity. Instead electrode B on the pad is electrode E_0. The main constant of the electrode array is after this equation:

$$K = \left\{\left(k_{AM}^{-1}-k_{E_0M}^{-1}\right)+k_{EM}^{-1}\times\eta\right\}^{-1}. \tag{16}$$

The coefficient of focusing is known like this:

$$\eta = \left(\frac{k_{AN}^{-1} - k_{AM}^{-1}}{k_{EM}^{-1} - k_{EN}^{-1}} \right) + \left(\frac{k_{E_0M}^{-1} - k_{E_0N}^{-1}}{k_{EM}^{-1} - k_{EN}^{-1}} \right). \tag{17}$$

Resistivity of rocks is described again with formula (8). For calculation of partial constants k_{AM} and k_{AN} there hold formulas (9) and (10). The partial constants k_{EM} and k_{EN} and the constants k_{E_0M} and k_{E_0N}, too, are directed with formulas denoted as (11), (12) and (13).

3.4 Microlaterolog – regulation on condition $U_N = 0$

Now, we have again different condition of focusing. Coefficient of focusing will be negative and its form derived is as follows:

$$\eta = -\, k_{EN} \times \left(k_{AN}^{-1} - k_{E_0N}^{-1} \right). \tag{18}$$

The main constant of array is this:

$$K = \left\{ \left(k_{AM}^{-1} - k_{E_0M}^{-1} \right) + k_{EM}^{-1} \times \eta \right\}^{-1} = \left\{ \left(k_{AM}^{-1} - k_{E_0M}^{-1} \right) - \frac{k_{EN}}{k_{EM}} \times \left(k_{AN}^{-1} - k_{E_0N}^{-1} \right) \right\}^{-1}. \tag{19}$$

Formula (8) holds again and all next formulas from (9) up to (13). Also here are exchange electrodes B and E_0.

4 The 5-electrode Microlaterolog with elliptical electrode array

4.1 Pseudo-Microlaterolog – regulation on condition $U_N = U_M$

Coefficient of focusing is managed by formula (6), the main constant of the electrode array by formula (7) and resistivity of rocks uses formula (8), RYŠAVÝ (2013). However, calculation of partial constants k_{AM} and k_{AN} is directed by other relations; see RYŠAVÝ (2017).

$$\left(\frac{k}{a} \right) = \frac{2\pi}{F_1 + F_2}, \tag{20}$$

$$F_1 = +\,2 \times \left(\frac{2}{\pi} \right) \times \left(\frac{a}{b} \right) \times \left[\mathrm{E}\left\{ \frac{A}{a} \right\} - \left(\frac{H}{a} + 1 \right)^{-1} \times \mathrm{E}\left\{ \left(\frac{A}{a} \right) \times \left(\frac{H}{a} + 1 \right)^{-1} \right\} \right], \text{ for } A < a \text{ and} \tag{21}$$

$$F_2 = +\,2 \times \left(\frac{2}{\pi} \right) \times \left[\mathrm{E}\left\{ \frac{B}{b} \right\} - \left(\frac{H}{b} + 1 \right)^{-1} \times \mathrm{E}\left\{ \left(\frac{B}{b} \right) \times \left(\frac{H}{b} + 1 \right)^{-1} \right\} \right] \text{ for } B < b. \tag{22}$$

where A = the big half-axis of ellipsis of current electrode A [m],
B = the small half-axis of ellipsis of current electrode A [m],
a = the big half-axis of inner ellipsis of elliptical annulus presenting potential electrodes M/N [m],
b = the small half-axis of inner ellipsis of elliptical annulus presenting potential electrodes M/N [m],
H = width of elliptical annulus for potential electrodes M/N [m].

The partial constants k_{EM} and k_{EN} and the constants k_{BM} and k_{BN}, too, have own new formulas after RYŠAVÝ (2017):

$$\left(\frac{k}{A}\right)=\frac{2\pi}{\sum_{i=1}^{4}F_i}, \tag{23}$$

$$F_1=+2\times\left(\frac{A}{B}\right)^{2}\times\left(\frac{a}{b}\right)^{-1}\times\left(\frac{L}{B}+1\right)^{-1}\times\frac{\left(\frac{H}{A}\right)\times\left(\frac{H}{A}+\frac{a}{A}\right)}{\left(\frac{H}{A}+\frac{a}{A}\right)\times\left(\frac{H}{B}+\frac{b}{B}\right)-\left(\frac{a}{A}\right)\times\left(\frac{b}{B}\right)}\times$$
$$\times\left[\left(\frac{\frac{H}{A}+\frac{a}{A}}{\frac{L}{A}+1}+1\right)\times\text{Argsinh}\left\{\left(\frac{A}{B}\right)^{-1}\times\left(\frac{\frac{L}{B}+1}{\frac{L}{A}+1}\right)\times\left(\frac{\frac{H}{A}+\frac{a}{A}}{\frac{L}{A}+1}+1\right)^{-1}\right\}-\left(\frac{\frac{H}{A}+\frac{a}{A}}{\frac{L}{A}+1}-1\right)\times\text{Argsinh}\left\{\left(\frac{A}{B}\right)^{-1}\times\left(\frac{\frac{L}{B}+1}{\frac{L}{A}+1}\right)\times\left(\frac{\frac{H}{A}+\frac{a}{A}}{\frac{L}{A}+1}-1\right)^{-1}\right\}\right], \tag{24}$$

$$F_2=+\left(\frac{a}{b}\right)\times\left(\frac{L}{A}+1\right)^{-2}\times\left(\frac{L}{B}+1\right)\times\frac{\left(\frac{H}{A}\right)\times\left(\frac{H}{A}+\frac{a}{A}\right)}{\left(\frac{H}{A}+\frac{a}{A}\right)\times\left(\frac{H}{B}+\frac{b}{B}\right)-\left(\frac{a}{A}\right)\times\left(\frac{b}{B}\right)}\times\left[\left(\frac{\frac{H}{B}+\frac{b}{B}}{\frac{L}{B}+1}+1\right)\times\text{Argsinh}\left\{\left(\frac{\frac{H}{B}+\frac{b}{B}}{\frac{L}{B}+1}+1\right)^{-1}\right\}-\left(\frac{\frac{H}{B}+\frac{b}{B}}{\frac{L}{B}+1}-1\right)\times\text{Argsinh}\left\{\left(\frac{\frac{H}{B}+\frac{b}{B}}{\frac{L}{B}+1}-1\right)^{-1}\right\}\right], \tag{25}$$

$$F_3=-2\times\left(\frac{A}{B}\right)\times\left(\frac{a}{b}\right)^{-1}\times\frac{\left(\frac{H}{A}\right)\times\left(\frac{H}{A}+\frac{a}{A}\right)}{\left(\frac{H}{A}+\frac{a}{A}\right)\times\left(\frac{H}{B}+\frac{b}{B}\right)-\left(\frac{a}{A}\right)\times\left(\frac{b}{B}\right)}\times$$

$$\times\left[\left(\frac{H}{A}+\frac{a}{A}+1\right)\times \text{Argsinh}\left\{\left(\frac{A}{B}\right)^{-1}\times\left(\frac{H}{A}+\frac{a}{A}+1\right)^{-1}\right\}-\left(\frac{H}{A}+\frac{a}{A}-1\right)\times \text{Argsinh}\left\{\left(\frac{A}{B}\right)^{-1}\times\left(\frac{H}{A}+\frac{a}{A}-1\right)^{-1}\right\}\right] \tag{26}$$

$$F_4=-\left(\frac{a}{b}\right)\times\frac{\left(\frac{H}{A}\right)\times\left(\frac{H}{A}+\frac{a}{A}\right)}{\left(\frac{H}{A}+\frac{a}{A}\right)\times\left(\frac{H}{B}+\frac{b}{B}\right)-\left(\frac{a}{A}\right)\times\left(\frac{b}{B}\right)}\times\left[\left(\frac{H}{B}+\frac{b}{B}+1\right)\times \text{Argsinh}\left\{\left(\frac{H}{B}+\frac{b}{B}+1\right)^{-1}\right\}-\left(\frac{H}{B}+\frac{b}{B}-1\right)\times \text{Argsinh}\left\{\left(\frac{H}{B}+\frac{b}{B}-1\right)^{-1}\right\}\right]. \tag{27}$$

where A = the big half-axis of inner ellipsis of elliptical annulus for potential electrodes M/N [m],
B = the small half-axis of inner ellipsis of elliptical annulus for potential electrodes M/N [m],
L = width of elliptical annulus for potential electrodes M/N [m],
a = the big half-axis of inner ellipsis of elliptical annulus for current electrodes E/B [m],
b = the small half-axis of inner ellipsis of elliptical annulus for current electrodes E/B [m],
H = width of elliptical annulus for current electrodes E/B [m].

Thanks to the presented formulas you can enumerate crucial characteristics K and η.

4.2 Pseudo-Microlaterolog – regulation on condition $U_N = 0$

Now again, we have different condition of focusing. Coefficient of focusing will be negative and it is formula (14):

$$\eta=-k_{EN}\times\left(k_{AN}^{-1}-k_{BN}^{-1}\right).$$

The main constant of the electrode array is again formula (15):

$$K=\left\{\left(k_{AM}^{-1}-k_{BM}^{-1}\right)+k_{EM}^{-1}\times\eta\right\}^{-1}=\left\{\left(k_{AM}^{-1}-k_{BM}^{-1}\right)-\frac{k_{EN}}{k_{EM}}\times\left(k_{AN}^{-1}-k_{BN}^{-1}\right)\right\}^{-1}.$$

Resistivity of rocks is described with formula (8). The partial constants are directed, however, with formulas from (20) up to (27). The electrode array is similar to one like it is in the fig.1; however, focusing is different, because electrodes are elliptical.

Microlaterolog of elliptical electrode array will not be presented here, because it is the same process like in the chapters 4.1 and 4.2 with all the before formulas and who is interested in, can personally deduce the relevant formulas.

5 The 4-electrode Microlaterolog with circular electrode array

5.1 Microlaterolog – regulation on condition $U_N = U_M$

This electrode array is called, too, as Classical Microlaterolog. In this case the current electrode B is not on the pad, but, it is grounded on the earth surface. That means it holds:

$$k_{BM}^{-1} = k_{BN}^{-1} = 0 . \qquad (28)$$

If you implement this condition into formulas (6) and (7), you shall get the following equations:

$$\eta = \left(\frac{k_{AN}^{-1} - k_{AM}^{-1}}{k_{EM}^{-1} - k_{EN}^{-1}} \right), \text{ and} \qquad (29)$$

$$K = \left\{ k_{AM}^{-1} + k_{EM}^{-1} \times \eta \right\}^{-1} . \qquad (30)$$

Resistivity of rocks is managed again with formula (8). Partial constants k_{AM} and k_{AN} are enumerated according to formulas (9), (10); constants k_{EM} and k_{EN} use formulas (11), (12) and (13). Type of Classic Microlaterolog with circular electrode array is presented in fig.3.

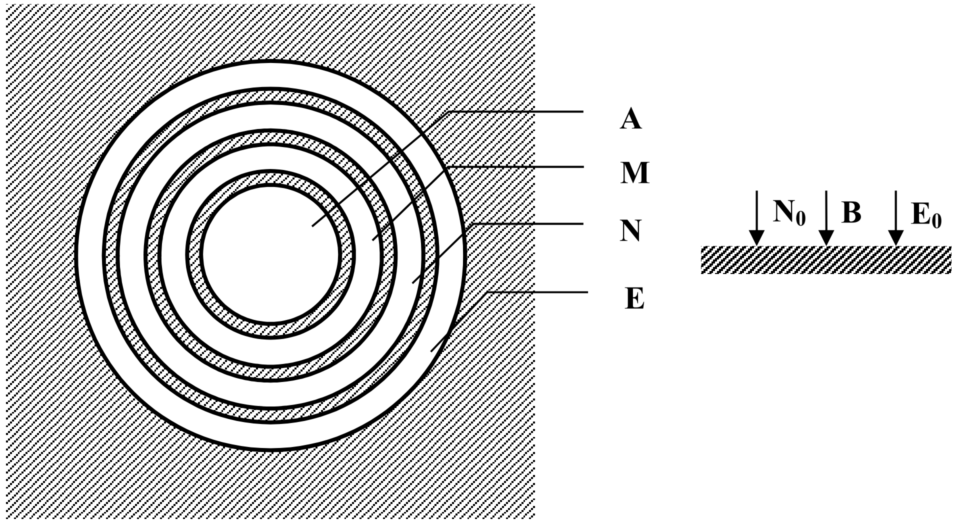


Fig.3 The 4-electrode Microlaterolog denoted like Classic Microlaterolog – the electrode array

5.2 Microlaterolog – regulation on condition $U_N = 0$

If you imply condition (28) into equations (14) and (15) you will receive these formulas:

$$\eta = - k_{EN} \times k_{AN}^{-1} = - \frac{k_{AN}^{-1}}{k_{EN}^{-1}} . \qquad (31)$$

$$K = \left\{ k_{AM}^{-1} + k_{EM}^{-1} \times \eta \right\}^{-1} = \left\{ k_{AM}^{-1} - \frac{k_{EN}}{k_{EM}} \times k_{AN}^{-1} \right\}^{-1} = \left\{ k_{AM}^{-1} - \frac{k_{AN}^{-1}}{k_{EN}^{-1}} \times k_{AN}^{-1} \right\}^{-1} . \qquad (32)$$

For resistivity of rock holds again formula (8); partial constants k_{AM} and k_{AN} are directed by formulas (9) and (10), constants k_{EM} and k_{EN} by formulas from (11) up to (13).

6 The 4-electrode Microlaterolog with elliptical electrode array

6.1 Microlaterolog – regulation on condition $U_N = U_M$

This electrode array use formulas (8), (29) and (30); these are basic for resistivity and characteristics K and η. Partial constants k_{AM} and k_{AN} are counted after formulas (20), (21) and (22). The resting constants k_{EM} and k_{EN} hold formulas from (23) up to (27).

6.2 Microlaterolog – regulation on condition $U_N = 0$

Resistivity and characteristics K and η are counted after formulas (8), (31) and (32). For partial constants k_{AM} and k_{AN} hold formulas from (20) to (22); for constants k_{EM} and k_{EN} then formulas from (23) up to (27).

7 The 2-electrode Microlaterolog with circular electrode array

7.1 Microlaterolog – regulation on condition $U_N = U_M$

This electrode array is characterized with condition that A ≡ M and E ≡ N; fig.4. Both electrodes are simultaneously the current and potential ones. What is important is that voltage being on the central electrode A ≡ M is zero. Simultaneously the voltage on the guard electrode E ≡ N is zero too. Consequence of that is that holds conditions $k_{AM}^{-1} = 0$ and $k_{EN}^{-1} = 0$. All resting constants are non-zero.

If you implement conditions that $k_{AM}^{-1} = 0$ and $k_{EN}^{-1} = 0$ into formulas (29) and (30), you will attain the following relations:

$$\eta = \left(k_{AN}^{-1} / k_{EM}^{-1} \right) \tag{33}$$

$$K = \left\{ k_{EM}^{-1} \times \eta \right\}^{-1} = k_{AN}. \tag{34}$$

Calculation of the partial constant k_{AN} is given by formulas (9) and (10) again. Resistivity of rocks is directed by formula (8).

The partial constant k_{EM}, RYŠAVÝ (2016), has also new relations:

$$\left(\frac{k}{D} \right) = \frac{2\pi}{F}, \text{ and} \tag{35}$$

$$F = 6 \times \frac{\left(\frac{2H}{D} + \frac{d}{D} \right)}{\left(\frac{2H}{D} + 2 \times \frac{d}{D} \right)} \times \left\{ \left(\frac{2H}{D} + \frac{d}{D} + 1 \right) \times \operatorname{Argsinh}\left(\frac{2H}{D} + \frac{d}{D} + 1 \right)^{-1} - \left(\frac{2H}{D} + \frac{d}{D} - 1 \right) \times \operatorname{Argsinh}\left(\frac{2H}{D} + \frac{d}{D} - 1 \right)^{-1} \right\} \text{ for } D < d. \tag{36}$$

Thus, we are able again to enumerate characteristics K and η. The electrode array for this type of Microlaterolog is presented on fig.4 for circular electrodes.

7.2 Microlaterolog – regulation on condition $U_N = 0$

If you imply conditions $k_{AM}^{-1} = 0$ and $k_{EN}^{-1} = 0$ into equations (31) and (32), you attain the following formulas:

$$\eta = -k_{EN} \times k_{AN}^{-1} = \infty . \qquad (37)$$

$$K = \left\{ k_{EM}^{-1} \times \eta \right\}^{-1} = \left\{ -\frac{k_{EN}}{k_{EM}} \times k_{AN}^{-1} \right\}^{-1} = -k_{EM} \times k_{AN} \times k_{EN}^{-1} = 0 . \qquad (38)$$

This case is unambiguously unpleasant and unsuitable for registration; just this is why not to use the variance of circular electrode array with this regulation.

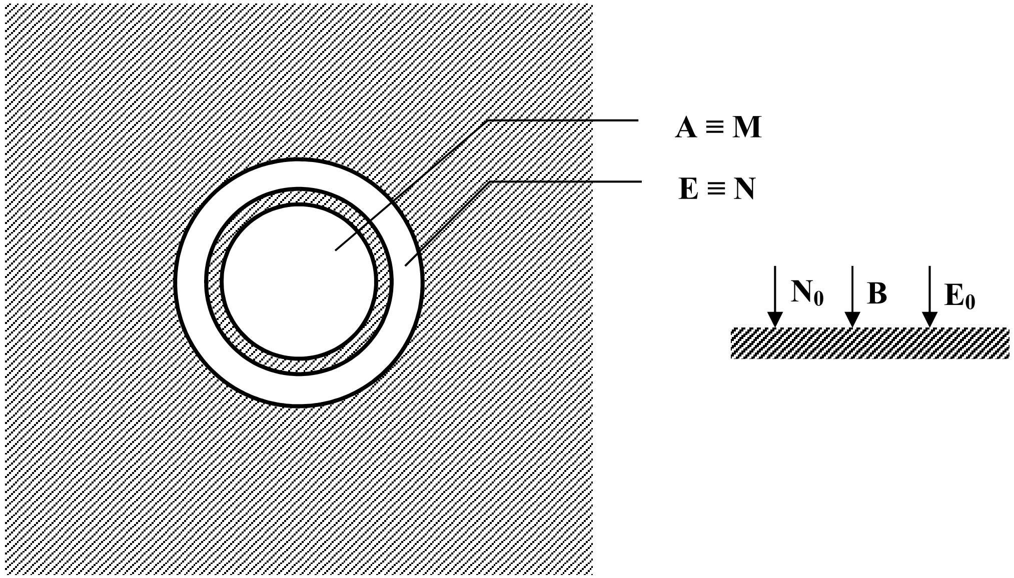


Fig.4 The 2-electrode Microlaterolog – the electrode array

8 The 2-electrode Microlaterolog with elliptical electrode array

8.1 Microlaterolog – regulation on condition $U_N = U_M$

Here holds again condition that voltage being on the central electrode A ≡ M is zero. Consequence of that is it holds $k_{AM}^{-1} = 0$. Simultaneously it holds that the voltage of the guard electrode E ≡ N is zero too. It presents that $k_{EN}^{-1} = 0$. Therefore coefficient of focusing respects formula (33) and the main constant of the electrode array formula (34). Resistivity of rocks is directed by formula (8), as well. The partial constant k_{AN} uses formulas (20), (21) and (22). Calculation of the partial constant k_{EM} is expressed by new formulas from (39) up to (41). The formulas hold under conditions that A < a, and simultaneously B < b.

$$\left(\frac{k}{A}\right) = \frac{2\pi}{F_1 + F_2} , \qquad (39)$$

$$F_1 = +2 \times \left(\frac{A}{B}\right)^2 \times \left(\frac{a}{b}\right)^{-1} \times \frac{\left(\frac{H}{A}\right) \times \left(\frac{H}{A} + \frac{a}{A}\right)}{\left(\frac{H}{A} + \frac{a}{A}\right) \times \left(\frac{H}{B} + \frac{b}{B}\right) - \left(\frac{a}{A}\right) \times \left(\frac{b}{B}\right)} \times$$

$$\times\left[\left(\frac{H}{A}+\frac{a}{A}+1\right)\times \mathrm{Argsinh}\left\{\left(\frac{A}{B}\right)^{-1}\times\left(\frac{H}{A}+\frac{a}{A}+1\right)^{-1}\right\}-\left(\frac{H}{A}+\frac{a}{A}-1\right)\times \mathrm{Argsinh}\left\{\left(\frac{A}{B}\right)^{-1}\times\left(\frac{H}{A}+\frac{a}{A}-1\right)^{-1}\right\}\right], \text{ and} \tag{40}$$

$$F_2=+\left(\frac{a}{b}\right)\times\frac{\left(\frac{H}{A}\right)\times\left(\frac{H}{A}+\frac{a}{A}\right)}{\left(\frac{H}{A}+\frac{a}{A}\right)\times\left(\frac{H}{B}+\frac{b}{B}\right)-\left(\frac{a}{A}\right)\times\left(\frac{b}{B}\right)}\times\left[\left(\frac{H}{B}+\frac{b}{B}+1\right)\times \mathrm{Argsinh}\left\{\left(\frac{H}{B}+\frac{b}{B}+1\right)^{-1}\right\}-\left(\frac{H}{B}+\frac{b}{B}-1\right)\times \mathrm{Argsinh}\left\{\left(\frac{H}{B}+\frac{b}{B}-1\right)^{-1}\right\}\right]. \tag{41}$$

8.2 Microlaterolog – regulation on condition $U_N = 0$

Characteristic η is directed by formula (37), whereas, characteristic K has formula (38). The case is again unsuitable for registering.

9 The 2-electrode Microlaterolog with stretched elliptical electrode array – Proximity Log

Such array is presented in fig.5. For the coefficient of focusing there is valid formula (33) again; the main constant of the electrode array is managed by formula (34). Resistivity of rocks respects again formula (8). Proximity Log is represented by stretched elliptical electrode array. That means that there exist the following conditions: $a \ll b$ and $A \ll B$. The symbols are half-axes of ellipses. The electrode array has deeper penetration of focusing electric lines into the borehole wall than it was for usual focusing electrode arrays. That is why this array is used for events of deeper invasion zone than it is usual.

The partial constant k_{AN} is possible to enumerate thanks to condition that $(a/b) \to 0$ into equation (21). Then holds that $F_1 = 0$, whereas $F_2 = F \neq 0$, see (22). You will receive these formulas:

$$\left(\frac{k}{a}\right)=\frac{2\pi}{F}, \tag{42}$$

$$F \approx +2\times\left(\frac{2}{\pi}\right)\times\left[\mathrm{E}\left\{\frac{B}{b}\right\}-\left(\frac{H}{b}+1\right)^{-1}\times \mathrm{E}\left\{\left(\frac{B}{b}\right)\times\left(\frac{H}{b}+1\right)^{-1}\right\}\right]. \tag{43}$$

The constant k_{EM} uses the following formulas:

$$\left(\frac{k}{A}\right)=\frac{2\pi}{F},$$

$$F \approx +2\times\left(\frac{A}{B}\right)^{2}\times\left(\frac{a}{b}\right)^{-1}\times\frac{\left(\frac{H}{A}\right)\times\left(\frac{H}{A}+\frac{a}{A}\right)}{\left(\frac{H}{A}+\frac{a}{A}\right)\times\left(\frac{H}{B}+\frac{b}{B}\right)-\left(\frac{a}{A}\right)\times\left(\frac{b}{B}\right)}\times$$

$$\times\left\{\left[\begin{array}{l}\left(\frac{H}{A}+\frac{a}{A}+1\right)\times \operatorname{Argsinh}\left\{\left(\frac{A}{B}\right)^{-1}\times\left(\frac{H}{A}+\frac{a}{A}+1\right)^{-1}\right\}- \\ -\left(\frac{H}{A}+\frac{a}{A}-1\right)\times \operatorname{Argsinh}\left\{\left(\frac{A}{B}\right)^{-1}\times\left(\frac{H}{A}+\frac{a}{A}-1\right)^{-1}\right\}\end{array}\right]\right\}. \qquad (44)$$

It is because for (a/b) →0 is formula (41) equal zero. Then holds that $F = F_1$, see (40).

It needs to say that in the recent time the elliptical electrode arrays are replaced with rectangular electrode systems. The reason is a simpler manufacturing. The electrodes have form of oblong. The electrode pads have two basic variances. The first is on basis of Pseudo-Microlaterog when on the pad is feeding electrode B, whereas, guard electrode E_0 is in an infinity. Such variance is Proximity Log.

The second is on base of Microlaterolog. Micro Spherically Focused Log is denoted as MSFL when in the infinity is electrode B and guard electrode E_0 is on the pad. Between both variances can be a lot of different ones what depends on the electrode number. It is evident in the fig.6. The first is the pad marked like PL presenting Proximity Log. The second has label like MSFL, i.e., Micro Spherically Focused Log. The deeper focusing has the first. The effective space of current contours for Proximity Log is shaped like the opening funnel towards beds, whereas, for Micro Spherically Focused Log it looks like the cut in half apple. The deeper focusing offers question whether measurement is not influenced a bit with the resistivity of non-invaded zone. It seems the pad of MSFL will be more convenient. What is common for both arrays is the

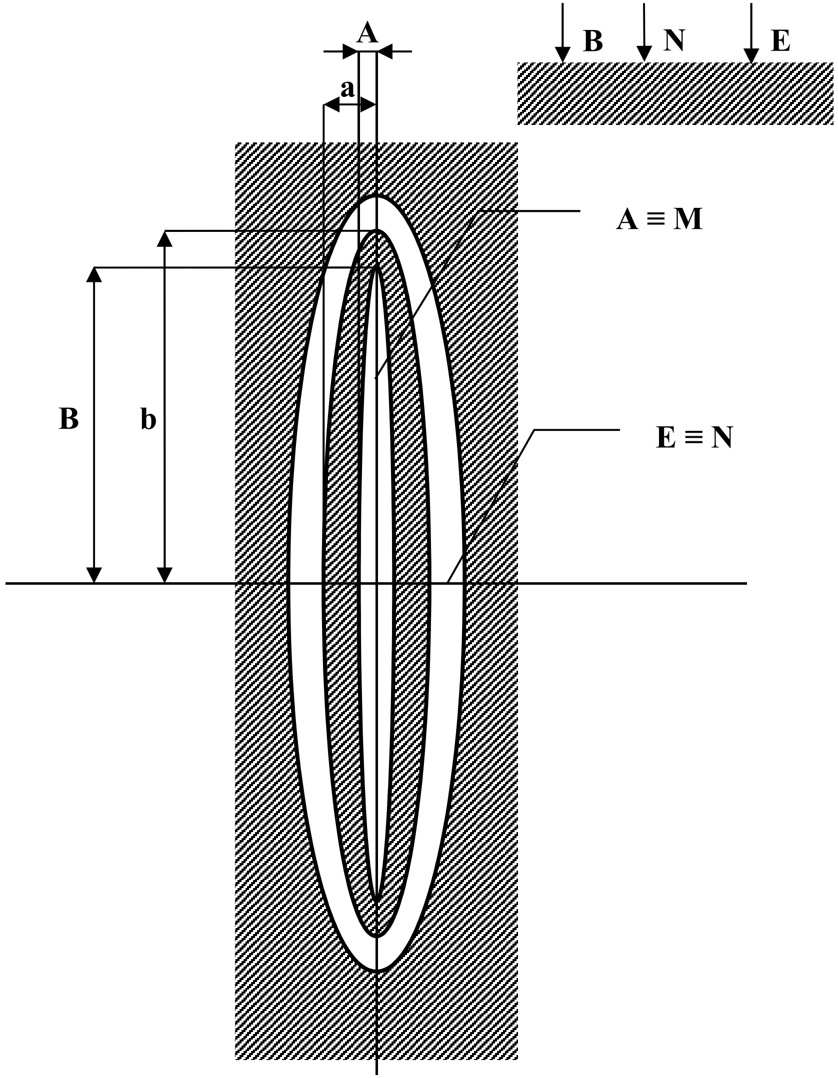
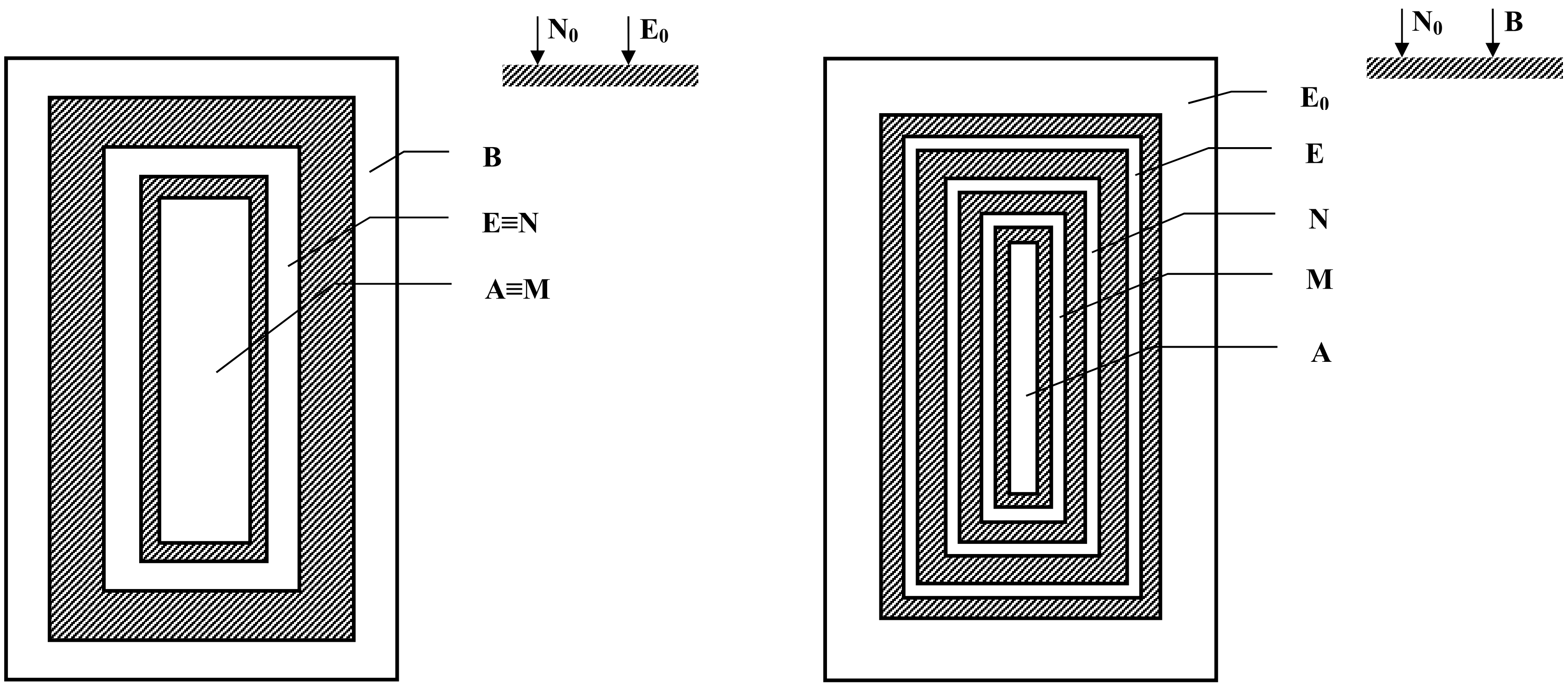


Fig.5 Proximity Log as the 2-electrode elliptical stretched Microlaterolog

rectangular feeding electrode remarked as A that determines the whole shape of pads. As regards derivation of partial constants of the orthogonal electrode systems it can be made in the same way as it was for elliptical and circular electrode systems. One must only respect different geometry of orthogonal electrodes.



a. PL – Proximity Log **b. MSFL – Micro Spherically Focused Log**

Fig.6 Depiction pads for Proximity Log and Micro Spherically Focused Log

10 An optimal electrode array for Microlaterolog

Principe of an optimal electrode array is based on two rules: the potential electrodes must be as wide as possible, whereas, the current electrodes must be as narrow as possible. If it is case of the central current electrode A, it must be the point current one which simultaneously fills almost all surface of inner annulus of potential electrode. It holds that the lower surface of the current electrode is the higher current density is. If it is about the elliptical electrode array, the central current electrode will be very short and thin ellipsis practically looking like an abscissa.

Both potential electrodes M and N, in contrary, must fill almost completely all surface of inner annulus the current one denoted as electrode E. Both are equally wide and it holds that insulant annuli between potential/current electrodes are very thin but functional.

The current electrode E must be shaped as a thin annulus. Again holds that the lower surface of the current electrode is the higher current density is.

Principe of optimization of electrodes you can apply when each of electrodes has the only function; when it is only potential one or only current one. When an electrode has double function what means that it is the potential and current one together, the rules of optimization cannot be implied. So you can have 5-electrode Microlaterolog or the 5-electrode Pseudo-Microlaterog, 4-electrode Microlaterog, however not, 2-electrode Microlaterolog. For the last one it does not hold and dimensions of electrode array you must solve in other way.

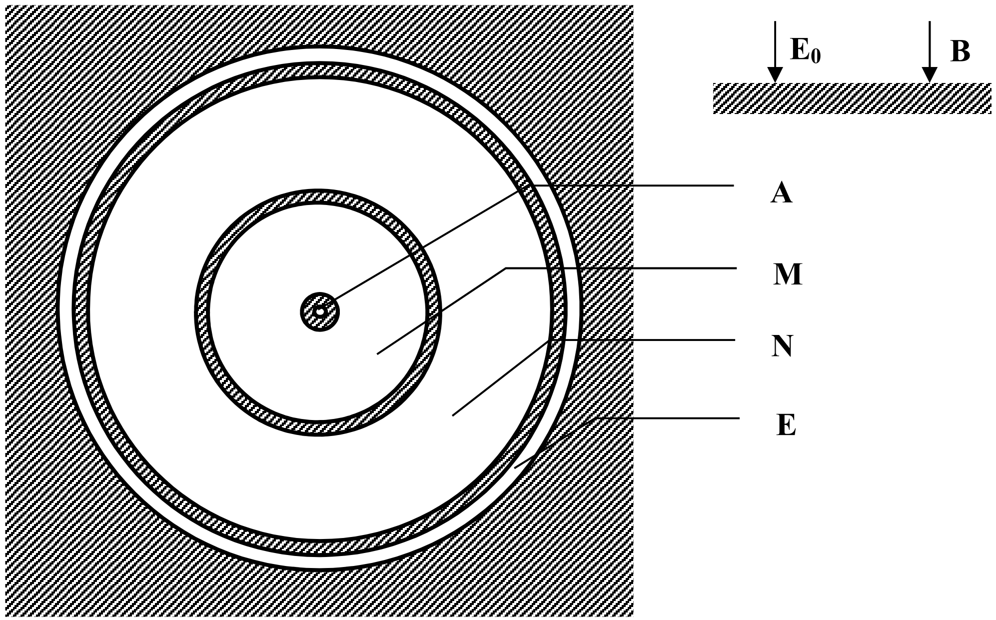


Fig. 7 The 4-electrode Microlaterolog denoted like Classic Microlaterolog – the optimal electrode array

Principe of optimization was explained in the before made works RYŠAVÝ (2017). The central current electrode has an optimal visual aspect like a current point for circular shape and almost a current abscissa for elliptical shape. The guard current electrode in the optimal shape is very narrow annulus being either circular or elliptic resembling contours of circle/ellipse. In opposite to them the potential electrodes ought to be as wide as possible. Their size is determined with distance being between both current electrodes. It is goes out from equation being valid for fig.7:

$$2W_{PE} + 3W_I + \frac{D}{2} = \frac{d}{2}, \qquad (45)$$

where D… the diameter of the current feeding electrode A [m],

W_{PE}… the width of potential electrode M/N [m],

W_I ... the width of annulus between electrodes; made from insulator [m] and

d… the inner diameter of the current guard annulus.

In equation (45) it is supposed that three annuli of insulator between electrodes are of the same width. They should be very narrow. Their smallest width depends on properties of the used dielectric. However, it needs to admit that the width between the current and potential electrodes can be different than the width between two potential electrodes is. If you know, what the width of annuli is, you can easy from formula (45) to count the width of the potential electrodes M and N.

In fig. 7 the proposal of such optimal electrode array is presented; for circular electrodes of Microlaterolog with 4 electrodes. The current electrodes are small and narrow, whereas, the potential ones are wide. The 5-electrode Pseudo-Microlaterog has electrode array almost the same, only current electrode E is enwheeld with uniformly-thin current electrode B. The same holds too for the 5-electrode Microlaterolog; instead of electrode B it is electrode E_0. The mentioned principle is valid for multi-electrode arrays having more than two electrodes.

When it is the 2-electrode Microlaterolog the before cannot be. You can do it for circular array. There are both electrodes simultaneously current and potential; A ≡ M and E ≡ N. Try to predict what dimensions of the electrode array ought to be. You can suppose that holds H = (D/2), where **H** is width of the annulus of electrode E ≡ N having the inner diameter remarked as **d** and **D** is diameter of the central electrode A ≡ M. Let express formulas for surfaces of both electrodes A ≡ M and E ≡ N.

$$S_A = \pi \times \left(\frac{D}{2}\right)^2 \text{ and } S_E = \pi \times \left[\left(\frac{d}{2} + H\right)^2 - \left(\frac{d}{2}\right)^2\right].$$

If you imply condition that H = (D/2), equation for annulus changes on the following expression.

$$S_E = \pi \times \left[\left(\frac{d}{2} + \frac{D}{2}\right)^2 - \left(\frac{d}{2}\right)^2\right] = \pi \times \left(d + \frac{D}{2}\right) \times \left(\frac{D}{2}\right) = \pi \times \left(\frac{D}{2}\right)^2 + \pi \times d \times \left(\frac{D}{2}\right) = P_A + \pi \times d \times \left(\frac{D}{2}\right).$$

For D→0, the point central electrode holds that $S_E \approx S_A$. If holds that d→D then $S_E \approx 3S_A$. You see that condition H = (D/2) is well acceptable; possible changes can be with varying characteristics **d** and **D**. Conclusion is that for the 2-electrode Microlaterolog both surfaces of electrodes ought to be approximately same when H = (D/2).

12 Elimination of the electrode potentials

For Microlaterolog the electrode potentials are permanently serious danger. Principle of non-polarized electrode used for surface geoelectrical registering is not in the borehole usable. However, there exists other way being more universal that allows either completely or almost completely eliminating an influence of the electrode potentials.

There are two ways how to do that. The first one, less universal, is an electrode is made of difficulty-polarized materials. It is about material having the electrode potentials as low as possible together only with tiny corrosion. The electrodes can be manufactured from brass or soft iron, i.e. Fe^{3+} having the lowest electrode potential to hydrogen. The technically-pure iron is a soft iron that does not corrode. It can be used for manufacturing of electrodes. However, more usual is the iron is galvanized with elements like Co, Ni or Cd or manufactured as iron - alloy containing Co, Ni or Cd. The electrode potentials must be so insignificant you can neglect them. It is about materials where iron prevails at least 50% like Kovar, Permalloy and other are. Density of such materials varies in the interval 7.8 –9.0 kg / m^3. This way manages electrode potentials significantly to supress but not totally to eliminate.

The second way is all universal because eliminates the electrode potentials totally. Elimination generates spontaneously when electrodes are dunked with mud. If electrodes and mud are not in a contact, the process of elimination of the electrode potentials stops. Producers manufacture the electrode pad where electrodes are divided into several segments roughly the same shape and dimensions. The segments are close to themselves and they are short-circuited. Each of segments is insulated from all others. The insulator is firm flexible rubber; in the rubber there are hidden conductive all rubber-insulated links between segments. In fig.8 there are depicted two electrode arrays for the 2-electrode Microlaterolog. The links in the rubber are in red. In case **a.** each of both electrodes are segmented, in case **b.** the only electrode is segmented; in such case it is about combination of both ways of elimination.

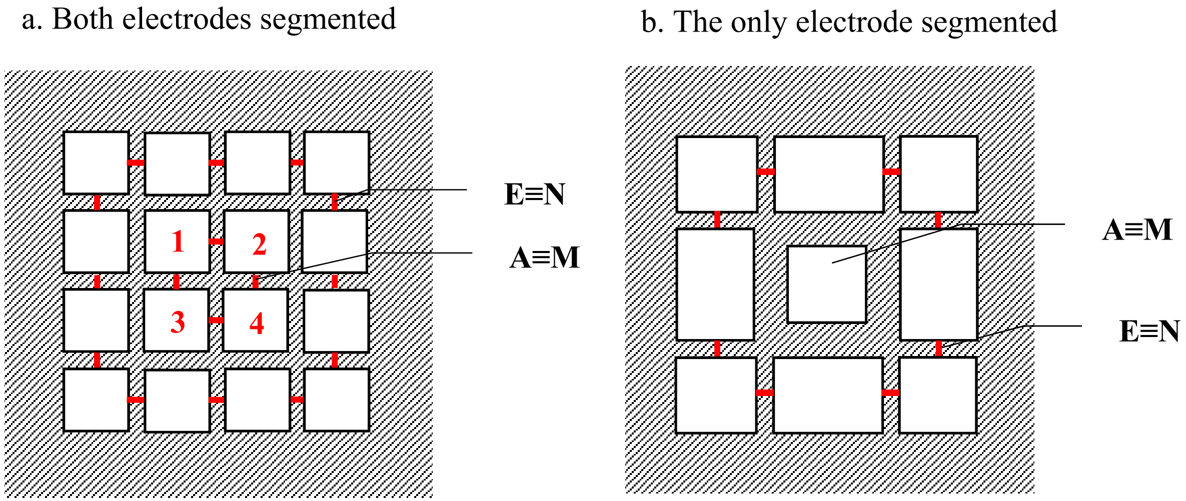


Fig.8 The 2-electrode Microlaterolog – types of segmented electrodes

Producers such electrode arrays manufacture, however, they did not explain how segmented electrode eliminates the electrode potentials. Therefore I should like shortly to explain activity of such electrode. More about is in RYŠAVÝ (2006). If the segmented electrode is in the mud on the surface of each segments forms galvanic cell. On the surface there exists the electric double layer; the metal has negative charge, whereas, mud has positive charge.

All galvanic cells are independent; however, segments are interconnected in the loop. You can see it in fig.8. Let's take electrode A ≡ M from case a. when the electrode is divided into four segments. We receive these dyads: (1,2); (1,3); (1,4); (2,3); (2,4) and (3,4). For every of dyads it holds that between two segments there flow electric currents having the same magnitude but inverse orientation. It results in that the final electric current between two segments is zero and that is why that final voltage on two segments is zero all the time when segments have a contact with mud.

This process is characteristic for all dyads. It results in that on the surface electrodes A ≡ M and E ≡ N there is permanently zero voltage of the electrode potentials. You have in so way the really non-polarized electrode for borehole. What is important is the rubber between metal segments must never be soaked through totally, because it would be then the only big galvanic segment. However, it would hold, if rubber among all four segments has been soaked. It is required soaking to be local and not too deep, so conductive links can stay on dry. In such case elimination of the electrode potentials is running.

Let's suppose that the rubber insulator for dyad (1, 2) is not functional. Segments 1 and 2 will create the only segment denoted as 1+2. For the partially-soaked through electrode A ≡ M there will formed only three dyads: (1+2, 3); (1+2, 4) and (3, 4). These dyads, even if they are three, make to keep zero voltage on the surface of electrode. It holds even when two dyads are non-functional, (1, 2) and (1, 3), simultaneously; then you have the only dyad (1+2+3, 4) which is still able to eliminate the electrode potentials. It results in conclusion that is very expedient to have an electrode divided at more segments than two.

The segmented electrodes can be squares, but can be too oblongs, possibly, it can be combination of both; it is in fig.8 It is convenient when you have Proximity Log or MSFL system. The electrodes can be segmented too for circular or elliptical electrodes; however, engineering production of such electrodes is sophisticated and expensive. That is why the segmented electrodes are formed with rectangular figures.

13 Calibration of resistivity

Calibration is identical as calibration for Laterolog. There exist series of resistors having known electrical resistance in [Ωm]. The resistors present primary standards for calibration. The simulated resistivity is defined thanks to relation:

$$R^* = R_0 \times K\ , \qquad (46)$$

where R_0 = the electrical resistance of resistor [Ωm],

K = the main constant of the electrode array [m], and

R^* = the simulated resistivity of rocks [Ωm].

Deflection of voltage evoked on the resistor, which I observe, is determined by relation:

$$l^* = \frac{R^*}{n}\ , \qquad (47)$$

where n = the step of linear scale [Ωm/ 1cm], and

l^* = deflection of the voltage observed [cm].

It is advisable to have a secondary etalon, for example, the pit filled with fresh water. You can determine its resistivity with the help of primary etalons with an allowed error. You have periodically to control resistivity of fresh water in the current time. Thanks to such secondary etalon it is possible to inspect all registration equipment including the electrode tool, cable and the surface panel together. The well-adjusted equipment has stabilized deflection in the range of permissible deviations of fresh water.

14 Conclusions

On the base of this analysis here are these conclusions:

- Theory of the controlled current regulation makes easy explanation of all phenomenona being common for Laterolog and Microlaterolog.

- For Microlaterolog there are again two significant characteristics: coefficient of focusing η and the main constant of the electrode array K. Both mentioned characteristics are exactly counted due to an exact calculating of the partial constants after the before derived formulas. It has great significance in the practice.
- Conditions for Microlaterolog can be following: the current regulation with the help of the guard electrode E to be filled condition that $U_N = U_M$. This variance of focusing is demanded very oft. You register $R \approx R_i$.
- Next using of Microlaterolog can be that holds condition of focusing $U_N = 0$. It is used for registering of resistivity of flushed zone when $R \approx R_{xo}$ in case that holds $R_i >> R_s$. Next application is in carbonates. There holds that $R \approx 0$ for $R_i << R_s$. Very low deflections close to zero have thin sandy beds, joint systems and the mylonite zones in carbonates. However, variance $U_N = 0$ is less used.
- The electrode array must be concentric. Its form is circular, elliptical and rectangular.
- We distinguish these variances of Microlaterolog: 5-electrode Microlaterolog /Pseudo- Microlaterolog, 4-electrode Microlaterolog, further, 2-electrode Microlaterolog when there hold conditions that $A \equiv M$ and $E \equiv N$, and finally, 2-electrode Microlaterolog having enormously stretched elliptical electrode array denoted as Proximity Log.
- The 5-electrode Microlaterolog denoted as Pseudo- Microlaterolog has thanks to electrode B the least penetration of current contours into bed. It can reliably register characteristic of the flushed zone R_{x_0} .
- Special systems are rectangular ones as Proximity Log and Micro Spherically Focused Log, shortly MSFL.
- Electrode system ought to be optimized.
- For optimized electrode system holds that the surface of both potential electrode annuli being inside of the electrode array should be as big as possible, whereas, the surface of the outer current annulus of the guard electrode must be as narrow as possible.
- The current electrode of optimized electrode system can look then like an elliptic/circular contour. Simultaneously holds that the central current feeding electrode must be as small as possible, but too must cover almost all the inner surface of potential annulus.
- It presents that not only between the current and potential electrodes but too between both potential electrodes is very thin but well-functional insulator.
- Electrodes are quite often segmented due to the electrode potentials. The segmented electrodes eliminate such potentials totally.
- Calibration of the resistivity of rocks is very simple. It is the same way like it was for Laterolog when there had been used series of resistors presenting primary standards.

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Author
[1] RNDr. František Ryšavý, Lesní 3, 695 03 Hodonín, Czech Republic, rysavy.frantisek@seznam.cz