

INTERPRETATION OF THREE-LAYER CURVES OF FREQUENCY ELECTROMAGNETIC SOUNDINGS OF TYPES \$A\$ AND \$H\$

B. S. Ènenstein

1966

SovietRxiv

View the original and related papers at <https://sovietrxiv.org/items/ru-196601.32527>

Source: Math-Net.Ru and CyberLeninka. Machine translation. Verify with the original.

Abstract

Full Text

UDC 550.837

GEOPHYSICS

B. S. ENENSHTEIN

INTERPRETATION OF THREE-LAYER CURVES OF FREQUENCY ELECTROMAGNETIC SOUNDINGS OF TYPES *A* AND *H*

(Presented by Academician A. V. Peive, September 23, 1965)

In ⁽¹⁾ a method is described for interpreting three-layer curves of electromagnetic soundings of types *K* and *Q*, obtained with large spacings *r*, based on the use of a curve-transformation procedure. This procedure will also be used for interpreting three-layer curves of types *A* and *H*, obtained with large *r*.

However, as is shown below, in order to ensure a satisfactory interpretation of three-layer curves of types *A* and *H*, it is not sufficient to use only the transformation procedure, as for curves of types *K* and *Q*; it is necessary, in addition, to make use of the symmetry property of frequency soundings, which consists in the fact that curves of type *H* with parameters $\rho_1; h_1; h_2/h_1 = \nu_2^H; \rho_2/\rho_1 = \mu_2^H; \mu_{13}^H = \rho_3/\rho_1$ correspond to curves of type *K* reflected in mirror fashion with respect to the horizontal axis $\rho = 1$, with parameters $\rho_1; h_1; \nu_2^K = \nu_2^H/\mu_2^H; \mu_2^K = 1/\mu_2^H; \mu_3^K = 1/\mu_3^H$. The same holds between three-layer curves of types *A* and *Q* ^(2, 3).

The method of transforming three-layer curves of electromagnetic soundings of types *K* and *Q*, described in ⁽¹⁾, consists in the following: the interpreted curve, representing a section in which the lower bed has a finite resistivity, is replaced by a curve representing the same section but with the lower bed having a resistivity equal to zero. After such a transformation of the curves, it becomes possible to carry out a quantitative interpretation and determine the values of the parameters of the section.

A different situation arises in the interpretation of three-layer curves of type *A* (Fig. 1, curve *I*) and type *H*. In this case it proves impossible to carry out the interpretation by using only the one procedure developed for three-layer curves of types *K* and *Q*.

Indeed, if one uses the transformation procedure described in ⁽¹⁾ for curves of types *K* and *Q*, then with the aid of a three-layer chart of type *A*, constructed according to the same principle as the *K* chart described in ⁽¹⁾, it is possible

to transform curve I into curve II , characterizing a geoelectric section with the same parameters of the two upper layers, but with the value $\rho_3 \approx \infty$.

Interpretation of the left branch of curve I or II by the method described in ⁽⁴⁾ makes it possible, from the value $\rho_1 = 12 \text{ ohm} \cdot \text{m}$, taken directly from the left asymptotes of the curves, to determine the value $h_1 = 194 \text{ m}$.

For the interpretation of the entire curve II , with the aim of determining the quantities h_2 and ρ_2 , we choose an arbitrary value ρ_l (for example, $30 \text{ ohm} \cdot \text{m}$). We superpose the horizontal axis ($\rho = 1$) of the two-layer chart of type $\lambda_1/h_{1\infty}$ with the value $\rho_l = 30 \text{ ohm} \cdot \text{m}$ on the ChZ form in such a way that the right branches of curve II and of the chart curve $\rho_2/\rho_1 \approx \infty$ (dashed line III) coincide. As a result of superposing the right branches of the curves, the abscissa of the chart $\lambda_1/h_1 = 8$ (dashed line IV) coincides with the value $f_1 \approx 0.55 \text{ Hz}$ of the horizontal axis of curve II . Substituting the values $\rho_l = 30 \text{ ohm} \cdot \text{m}$ and $f_1 = 0.55 \text{ Hz}$ into the expression $\lambda/h = 8 = \sqrt{10\rho_l/h}\sqrt{f_1} = \sqrt{300/8}\sqrt{0.55}$, we find $h \approx 2920 \text{ m}$.

If, for interpretation, instead of $\rho_1 = 30 \text{ ohm} \cdot \text{m}$ one chooses another value, for example $B\rho_1 = 40 \text{ ohm} \cdot \text{m}$, then we find that, as a result of matching the right-hand branches of the curves, the abscissa of the master curve $\lambda_1/h_1 = 8$ coincides with another abscissa of the curve $f_2 = B^{-2/\tan \alpha} f_1$ ($f_2 = 0.41 \text{ Hz}$), where α is the angle between the right-hand branch of curve II and the abscissa axis, equal to $63^\circ 30'$ for $\rho_3 \approx \infty$. The new value h^* will be

$$h^* = \frac{\sqrt{10B\rho_1}}{8\sqrt{B^{-2/\tan \alpha} f_1}} = \frac{\sqrt{B}}{\sqrt{B^{-2/\tan \alpha}}} \frac{\sqrt{10\rho_1}}{\sqrt{f_1}} = B^{(\tan \alpha + 2)/2 \tan \alpha} h = B^k h$$

for $\alpha = 63^\circ 30'$; $\tan \alpha = 2$, $k = 1$, and $h^* = Bh$.

Thus, when the value ρ_1 chosen for interpretation is changed by a factor of B , the obtained value of h also changes by a factor of B . Consequently, direct interpretation of a curve of type A does not make it possible to determine the values h_2 and ρ_2 (h and ρ_1), but it does make it possible to determine the value S , equal to h/ρ_1 . The data presented apply equally to the interpretation of curves of type H .

It seems possible, however, to interpret three-layer FES curves of types A and H by the transformation method; but for this purpose it is necessary, as indicated above, to use the symmetry property and transform curves of types A and H , respectively, into curves of types Q and K , and then transform them into curves of the analogous type but with the resistivity of the lower layer equal to zero ($\rho_3 = 0$). A curve of type A , transformed in this way into a curve of type Q , is interpreted in accordance with the procedure described in (1).

Fig. 1

Fig. 1

Figure 1: Fig. 1

Fig. 2

Figure 2: Fig. 2

Let us explain the proposed procedure for interpreting three-layer curves of types *A* and *H* using a concrete example (Fig. 1, curve *I*). We read the value ρ_1 directly from the left asymptote of the curve ($12 \Omega \cdot \text{m}$). Using the value $\rho_1 = 12 \Omega \cdot \text{m}$ and the procedure described in (1), we determine $h_1 = 194 \text{ m}$. On the FES sheet of Fig. 1 we plot curve *V*, symmetric to curve *I* with respect to the horizontal axis $\rho_1 = 12 \Omega \cdot \text{m}$. By this we have transformed the curve of type *A* into a curve of type *Q*. We match the entire curve *V* with the most suitable curve, one of the three-layer master curves of type *Q* (Fig. 2), and, in accordance with the transformation principle, transfer to the FES sheet the master-curve curve with the same values of ρ_1 , h_1 , h_2 , and ρ_2 , but for $\rho_3 = 0$ (Fig. 1, curve *VI*)*.

* The master sheet presented in Fig. 2 is constructed according to the same principle as that used to construct the master curves of type *K* described in (1). The left group of curves (1–5) corresponds to the values $\rho_2 = \frac{1}{4}\rho_1$, $h_2 = \frac{1}{2}h_1$, and $\rho_3 = 0$, $\frac{1}{32}$, $\frac{1}{16}$, $\frac{1}{8}$, $\frac{1}{4}$. The following

We choose for the interpretation an arbitrary value of ρ (for example, $6 \Omega \cdot \text{m}$) and align the right branch of curve *VI* with the curve $\rho_2/\rho_1 = 0$ (dashed line *VII*) of the two-layer palette in such a way that the ordinate of the palette $\rho = 1$ coincides with the value $\rho = 6 \Omega \cdot \text{m}$. Using the procedure described in (1), we find that the abscissa of the palette $\lambda_1/h_1 = 8$ (dashed line *VIII*) coincides with the abscissa of the curve $f = 0.7 \text{ Hz}$. Substituting the values $\rho = 6 \Omega \cdot \text{m}$ and $f = 0.7 \text{ Hz}$, we obtain

$$h = \sqrt{10\rho}/8\sqrt{f} = \sqrt{60}/8\sqrt{0.7} = 1150 \text{ m}.$$

Since $h_1 = 194 \text{ m}$, it follows that $h_2 = 956 \text{ m}$ and $\nu_{12}^Q = h_2/h_1 = 4.8$.

Fig. 2

In accordance with the conditions of the symmetric transformation of the curves, the true value ν_{12}^A for curve *II* will be equal to ν_{12}^Q/μ_{12}^Q , obtained from curve *VI*. Since the value ν_{12}^Q is known to us (4.8), it remains to find $\mu_{12}^Q = \rho_2/\rho_1$.

To determine μ_{12}^Q , we use the procedure described in (1). From the known values $\nu_{12}^Q = 4.8$ and $\mu_{13} = 0$, we find, among the group of three-layer palettes of type *Q*, the curve that best coincides with curve *VI*. Since the palettes differ in the

parameter ρ_2 , the value of ρ_2 is thereby determined. In our case ρ_2 turns out to be equal to $\sim 1/4$. Hence we find

$$\nu_{12}^A = \nu_{12}^Q / \mu_{12}^Q = 4.8 / 0.25 = 19.2; \quad \mu_{12}^A = 1 / \mu_{12}^Q \approx 4.$$

$$h_2 = h_1 \nu_{12}^A = 194 \cdot 19.2 \approx 3720 \text{ m}; \quad \rho_2 = \rho_1 \mu_{12}^A = 12 \cdot 4 = 48 \text{ } \Omega \cdot \text{m}.$$

The described procedure for interpreting curves of type A , in which palettes of type Q are used, is equally suitable for interpreting curves of type H using palettes of type K .

Owing to the different resolving power of the electromagnetic sounding method with respect to layer thicknesses and their resistivities, the accuracy of determining the quantities h_2 and ρ_2 by the method described in (1) and in the present paper is not the same. Analysis of three-layer theoretical sounding curves of various types shows that the accuracy of determining the thickness of the second layer h_2 from curves K and Q depends on the accuracy with which the transformation of the original curve is performed and can be achieved within 5%. The accuracy of determining ρ_2 , however, can on average be achieved to the order of 10%, decreasing for small ν_2 .

The groups of curves of the palette correspond to the same ρ_2 and ρ_3 , but to different h_2 , namely: the 2nd group ($h_2 = h_1$), the 3rd group ($h_2 = 2h_1$), the 4th group ($h_2 = 3h_1$), the 5th group ($h_2 = 5h_1$), the 6th group ($h_2 = 9h_1$), and the 7th group ($h_2 = 24h_1$), to which curves 6-10 correspond. The palettes differ from one another in the value of μ_{12} .

Since, in the method described, to determine the value of h_2 from the A and H curves it is necessary first to find the value of φ_2 , the accuracy of determining h_2 from these curves cannot be greater than 10%.

In conclusion we note that the methods of interpretation developed in the present article and in (1) are also valid for curves of magnetotelluric soundings and for the left-hand parts of frequency-sounding and field-build-up curves obtained with small spacings ($r = 3h - 4h$).

Geological Institute
Academy of Sciences of the USSR

Received
22 IX 1965

REFERENCES

1. B. S. Epshtein, *Dokl. Akad. Nauk SSSR*, **168**, No. 4 (1966).

2. L. L. Vanyan, *Zhurn. prikl. geofiz.*, vol. 21 (1957).
3. M. V. Kalmykov, N. P. Vladimirov, *Izv. Akad. Nauk SSSR, ser. geofiz.*, No. 4 (1961).
4. B. S. Epshtein, *Izv. Akad. Nauk SSSR, ser. geofiz.*, No. 9 (1962).

Note: Figure translations are in progress. See original paper for figures.

Source: Math-Net.Ru and CyberLeninka. Machine translation. Verify with the original.