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

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Abstract

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B. S. ENENSHTEIN

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

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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 $\rho_1 = 12$ ohm • m, taken directly from the left asymptotes of the curves, to determine the value $h_1 = 194$ 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 ohm • m). We superpose the horizontal axis ($\rho = 1$) of the two-layer chart of type $\lambda_1/h_{1\infty}$ with the value $\rho_l = 30$ ohm • 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 $f_1 \approx 0.55$ Hz of the horizontal axis of curve II. Substituting the values $\rho_l = 30$ ohm • m and $f_1 = 0.55$ Hz into the expression $\lambda/h = 8 = \sqrt{10\rho_l}/h\sqrt{f_1} = \sqrt{300}/8\sqrt{0.55}$, we find $h \approx 2920$ m.

If, for interpretation, instead of $\rho_1 = 30\ \Omega \cdot$ m one chooses another value, for example $B\rho_1 = 40\ \Omega{\cdot}$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 $f_2 = B^{-2/\tan\alpha} f_1$ ($f_2 = 0.41$ Hz), where α is the angle between the right-hand branch of curve II and the abscissa axis, equal to $63°30'$ 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 $\alpha = 63°30'$; $\tan\alpha = 2$, $k = 1$, 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 $\Omega \cdot$ m). Using the value $\rho_1 = 12\ \Omega \cdot \mathrm{m}$ and the procedure described in (1), we determine $h_1 = 194$ m. On the FES sheet of Fig. 1 we plot curve V, symmetric to curve I with respect to the horizontal axis $\rho_1 = 12\ \Omega \cdot \mathrm{m}$. 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 $\Omega \cdot$ 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 $\rho = 6\ \Omega \cdot \mathrm{m}$. 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 $f = 0.7$ Hz. Substituting the values $\rho = 6\ \Omega \cdot \mathrm{m}$ and $f = 0.7$ Hz, we obtain

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

Since $h_1 = 194$ m, it follows that $h_2 = 956$ 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

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

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

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

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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.