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TYPE CURVES FOR RESISTIVITY SOUNDING WITH TWO-ELECTRODE, WENNER, SCHLUMBERGER, AND DIPOLE-DIPOLE ARRANGEMENTS FOR A TWO-, THREE-, FOUR-, AND FIVE-LAYERED MODEL

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ABSTRACT

Type curves for resistivity sounding with the two-electrode, Wenner, Schlumberger, and Dipole-Dipole arrays are presented for a two-, three-, four-, and five-layered earth, based on the theory of classification of relative resistivity sounding curves for an n-layered resistivity problem.

These graphs are useful to get an elementary knowledge of the interpretation of resistivity sounding curves for various electrode arrangements.

EXACT RELATIVE RESISTIVITY COMPUTATION FORMULAS FOR AN N-LAYER RESISTIVITY PROBLEM

Suppose an n-layer resistivity problem. Equations for computing the relative resistivity, which is defined as the ratio of apparent resistivity and resistivity of the first layer, at the surface of the model involved are:

for the two-electrode array

$$\rho_2^*(a) = 1 + F(a) \quad \text{........... (1)}$$

for the Wenner array

$$\rho_W^*(a) = 1 + 2F(a) - F(2a) \quad \text{...... (2)}$$

for the Schlumberger array

$$\rho_s^*(a,ma) = 1 + \frac{m}{m-1}F(a) - \frac{1}{m-1}F(ma) \quad \text{..... (3)}$$

where $m = (L+\ell)/(L-\ell)$

and for the Dipole-Dipole array

$$\rho_D^*(x,mx) = 1 + \frac{1}{2}\{(m+1)(m+2)F(mx) - 2m(m+2)F((m+1)x) + m(m+1)F((m+2)x)\} \quad \text{... (4)}$$

where x is the Dipole length and mx is the Dipole separation,

where $F(a) = 2a\int_0^\infty K_n(\lambda)J_0(\lambda a)d\lambda$,

a is the electrode separation, $K_n(\lambda)$ is the kernel function, J_0 is the Bessel function of the first kind of zero order, and λ is a parameter.

KINDS OF RELATIVE RESISTIVITY SOUNDING CURVES

The relative resistivity sounding curves for a two-layer earth can be grouped into two kinds of type curves depending on the condition such that $\rho_1<\rho_2$ and $\rho_1>\rho_2$. This is valid in the master curves by Tagg (1934) and Roman (1934). The procedure of classification is not affected by various electrode arrangements. Basically, the number of type curves involved can be expressed by

$$N_2 = 2 \quad \text{............ (5)}$$

The kernel function for a two-layer case is given in the form

$$K_2(\lambda) = \frac{k_1 e^{-2\lambda h_1}}{1-k_1 e^{-2\lambda h_1}} \quad \text{............. (6)}$$

The values of reflection coefficients k_1 take possitive and negative such that $1\geq k_1>0$ for $\rho_1<\rho_2$ and $-1\leq k_1<0$ for $\rho_1>\rho_2$.

Thus, such values of k_1 are substituted into (6), and carrying out the numerical computation of (1) to (4), we have two groups or types of relative resistivity sounding curves.

In general, the reflection coefficients $(k_1, k_2, ..., k_{n-1})$ included in the kernel function for an n-layer resistivity problem consist of n-1 kinds. In accordance with possitive and negative in each value, the number of combination of 2^{n-1} exists. This permits the classification of resistivity sounding curves. Thus, the number of type curves in the relative resistivity sounding curves for an n-layer resistivity problem can be expressed as

$$N_n = 2^{n-1} \quad \text{........... (7)}$$

NOTATION IN CLASSIFICATION

As illustarted in the foregoing section, fundamentally, RS (Resistivity Sounding) curves for a two-layer model can be grouped into two types: one is for resistivity constrast such that $\rho_1<\rho_2$, for which the curve groups are denoted by a numeral 1 with (1), and the other is for $\rho_1>\rho_2$, for

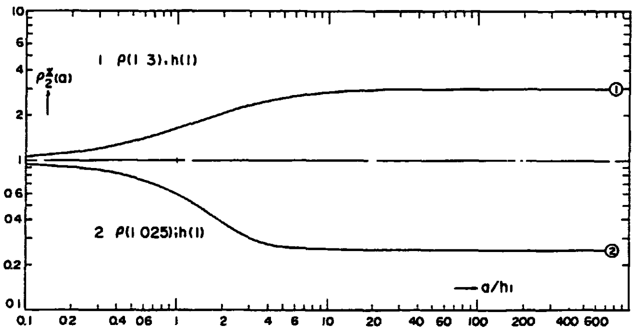

Fig. 1(a). Two types of curve groups for the two-layer model for the two electrode array

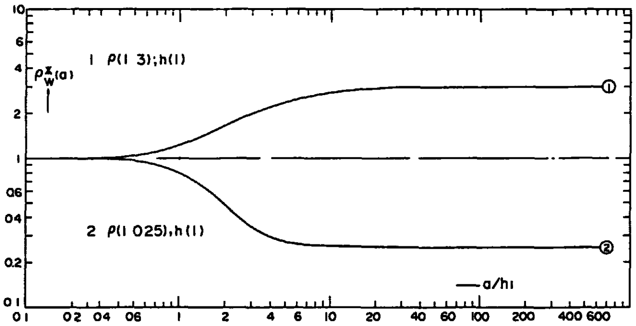

Fig. 1(b). Two types of curve groups for the two-layer model for the Wenner array

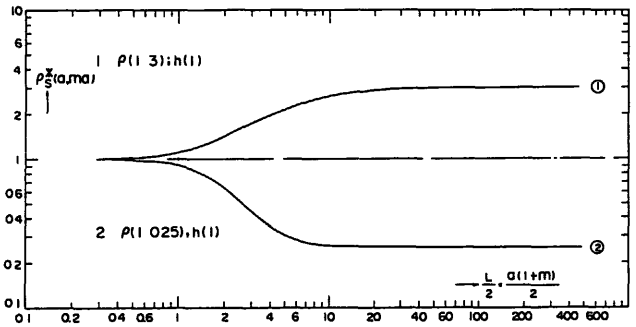

Fig. 1(c). Two types of curve groups for the two-layer model for the Schlumberger array

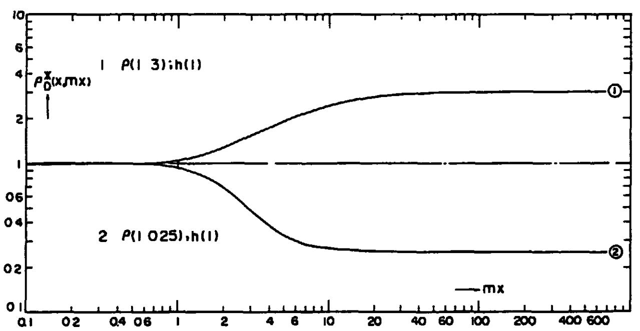

Fig. 1(d). Two types of curve groups for the two-layer model for the Dipole-Dipole array

which those are represented by a numeral 2 with (2). In short, relative RS curves for a two-layer can be grouped into

Type 1(1) for $\rho_1 < \rho_2$, and Type 2(2) for $\rho_1 > \rho_2$.

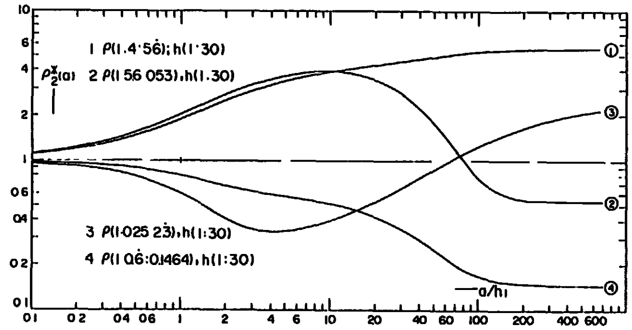

Fig. 2(a). Four type of curve groups for the three-layer model for the two electrode array

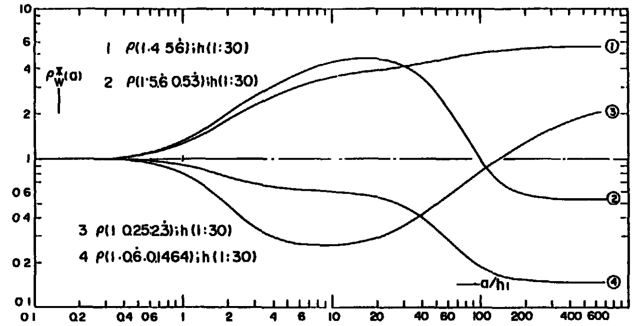

Fig. 2(b). Four types of curve groups for the three-layer model for the Wenner array

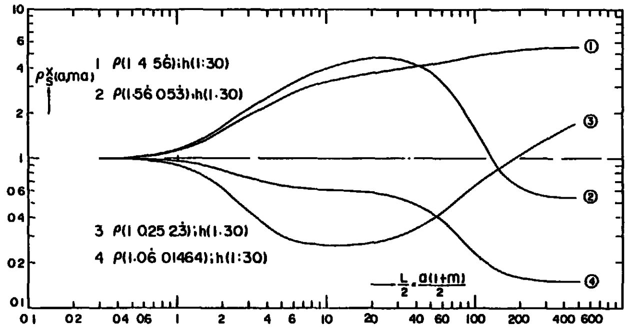

Fig. 2(c). Four types of curve groups for the three-layer model for the Schlumberger array

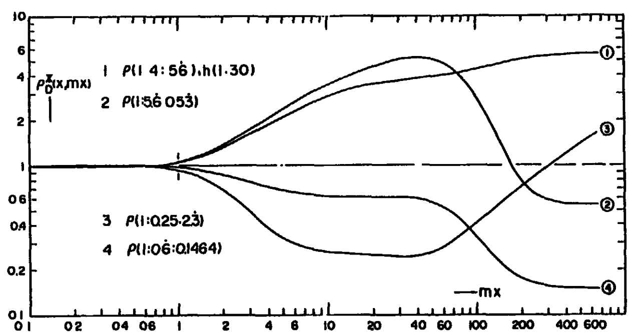

Fig. 2(d). Four types of curve groups for the three-layer model for the Dipole-Dipole array

For three layer RS curves it follows that 4 types can be grouped such that

Type 1(11) for $\rho_1 < \rho_2 < \rho_3$,

Type 2(12) for $\rho_1 < \rho_2 > \rho_3$,

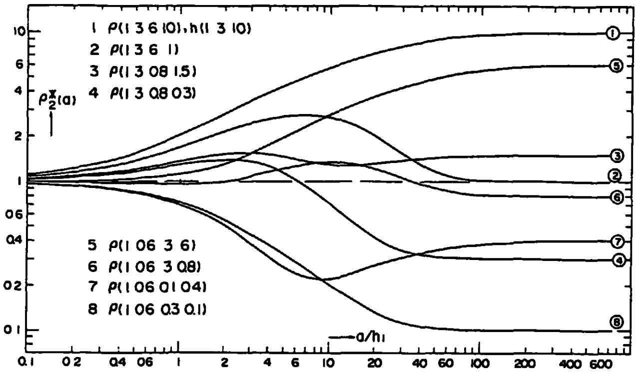

Fig. 3(a). Eight types of curve groups for the four-layer model for the two electrode array

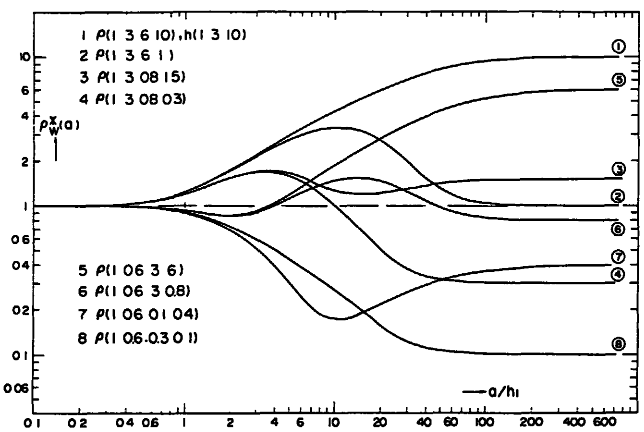

Fig. 3(b). Eight types of curve groups for the four-layer model for the Wenner array

Type 3(21) for $\rho_1 > \rho_2 < \rho_3$, and

Type 4(22) for $\rho_1 > \rho_2 > \rho_3$.

For four-layer RS curves there exists 8 types such that

Type 1(111) for $\rho_1 < \rho_2 < \rho_3 < \rho_4$,

Type 2(112) for $\rho_1 < \rho_2 < \rho_3 > \rho_4$,

Type 3(121) for $\rho_1 < \rho_2 > \rho_3 < \rho_4$,

Type 4(122) for $\rho_1 < \rho_2 > \rho_3 > \rho_4$,

Type 5(211) for $\rho_1 > \rho_2 < \rho_3 < \rho_4$,

Type 6(212) for $\rho_1 > \rho_2 < \rho_3 > \rho_4$,

Type 7(221) for $\rho_1 > \rho_2 > \rho_3 < \rho_4$, and

Type 8(222) for $\rho_1 > \rho_2 > \rho_3 > \rho_4$.

Similarly, five-layer RS curves can be classified into 16 types such that

Type 1(1111) for $\rho_1 < \rho_2 < \rho_3 < \rho_4 < \rho_5$,

Tyep 2(1112) for $\rho_1 < \rho_2 < \rho_3 < \rho_4 > \rho_5$,

Tyep 3(1121) for $\rho_1 < \rho_2 < \rho_3 > \rho_4 < \rho_5$,

Type 4(1122) for $\rho_1 < \rho_2 < \rho_3 > \rho_4 > \rho_5$,

Type 5(1211) for $\rho_1 < \rho_2 > \rho_3 < \rho_4 < \rho_5$,

Type 6(1212) for $\rho_1 < \rho_2 > \rho_3 < \rho_4 > \rho_5$,

Type 7(1221) for $\rho_1 < \rho_2 > \rho_3 > \rho_4 < \rho_5$,

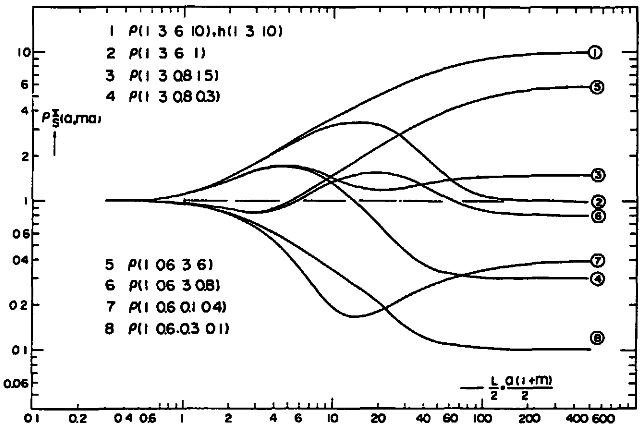

Fig. 3(c). Eight types of curve groups for the four-layer model for the Schlumberger array

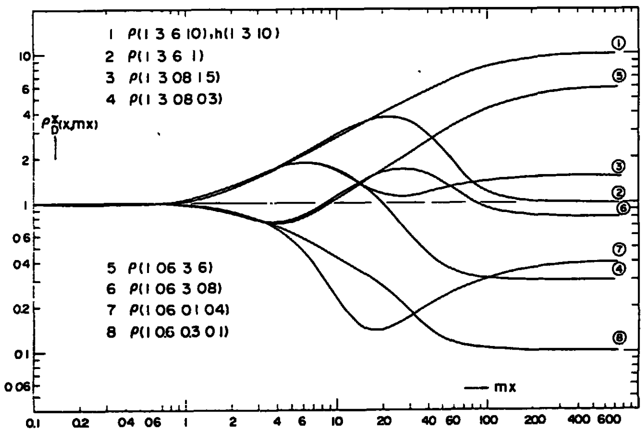

Fig. 3(d). Eight types of curve groups for the four-layer model for the Dipole-Dipole array

Type 8(1222) for $\rho_1 < \rho_2 > \rho_3 > \rho_4 > \rho_5$,

Type 9(2111) for $\rho_1 > \rho_2 < \rho_3 < \rho_4 < \rho_5$,

Type 10(2112) for $\rho_1 > \rho_2 < \rho_3 < \rho_4 > \rho_5$,

Type 11(2121) for $\rho_1 > \rho_2 < \rho_3 > \rho_4 < \rho_5$,

Type 12(2122) for $\rho_1 > \rho_2 < \rho_3 > \rho_4 > \rho_5$,

Type 13(2211) for $\rho_1 > \rho_2 > \rho_3 < \rho_4 < \rho_5$,

Type 14(2212) for $\rho_1 > \rho_2 > \rho_3 < \rho_4 > \rho_5$,

Type 15(2221) for $\rho_1 > \rho_2 > \rho_3 > \rho_4 < \rho_5$, and

Type 16(2222) for $\rho_1 > \rho_2 > \rho_3 > \rho_4 > \rho_5$.

GRAPHS OF RELATIVE RS CURVES FOR A TWO-, THREE-, FOUR-, AND FIVE-LAYER MODELS

The typical curves of curve groups for a two-, three-, four-, and five-layer cases are shown in Figs. 1, 2, 3, and 4 for two electrode, Wenner, Schlumberger, and Dipole-Dipole arrays with (a), (b), (c), and (d), respectively, and no difficulty is encountered in ascertaining their general feature. These calculations are due to a polynomial approximation of the kernel function (Onodera, 1963).

Depths of interfaces are selected as increased geometrical progression from upper to lower, so that each resistivity

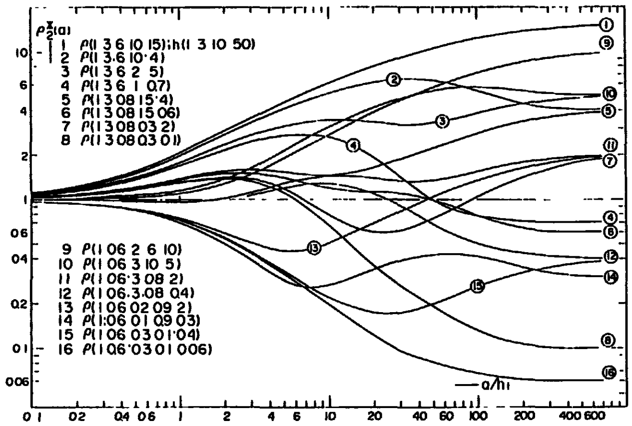

Fig. 4(a). Sixteen types of curve groups for the five-layer model for the two electrode array

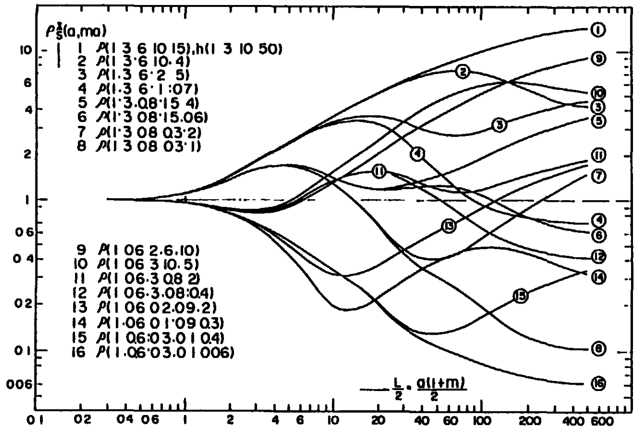

Fig. 4(c). Sixteen types of curve groups for the five-layer model for the Schlumberger array

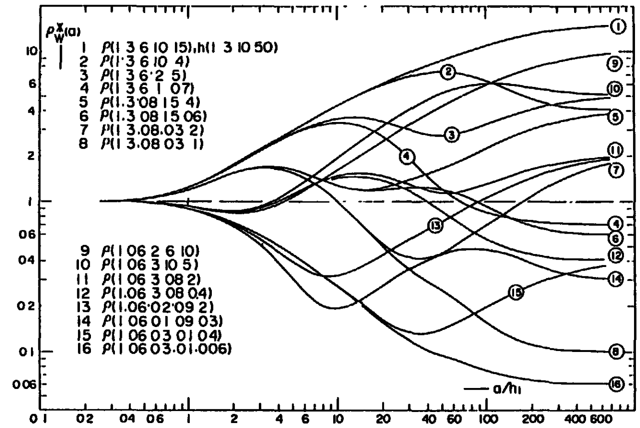

Fig. 4(b). Sixteen types of curve groups for the five-layer model for the Wenner array

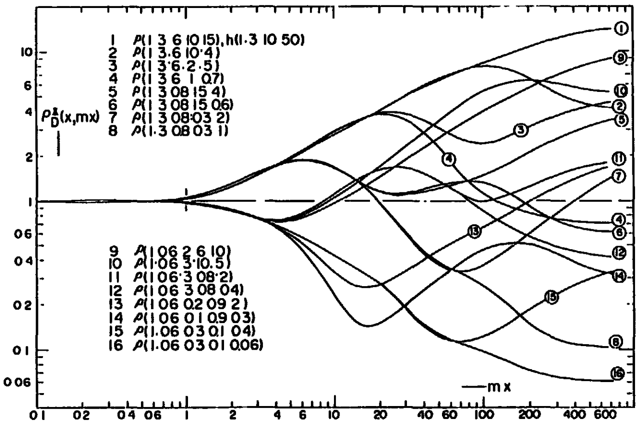

Fig. 4(d). Sixteen types of curve groups for the five-layer model for the Dipole-Dipole array

layer leflects clearly upon each relative resistivity sounding curve. For convenience, such a curve is called the type curve of the relative resistivity sounding curves, of which the interpretation is very easy.

EFFECT OF DEPTHS

If each of depths for a given model is close with each other, then it is impossible to classify the type curve for a given RS curve. This makes the interpretation of RS curve still worse, particularly, in the case of containing a thin layer.

CONCLUSION

The type curves for the relative resistivity sounding for a two-, three-, four-, and five-layer models were presented for the two electrode, Wenner, Schlumberger, and Dipole-Dipole arrangements.

These type curves furnish an elementary knowledge of the interpretation of resistivity sounding curves to us.

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