Short Note

On Rule of Thumb Interpretation of Restivity Gradient Array Data

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The so called resistivity gradient array, described by Whiteley (1973) and illustrated in figure 1, presents a unique opportunity for the application of semi-quantitative interpretation techniques based on potential theory. Large current electrode separations, as encountered in the resistivity gradient array, enable the applied potential field in the vicinity of the centre of the array to be closely approximated by a constant field (Kunetz, 1966). The assumption of a constant applied field considerably reduces the complexity of mathematical treatment.

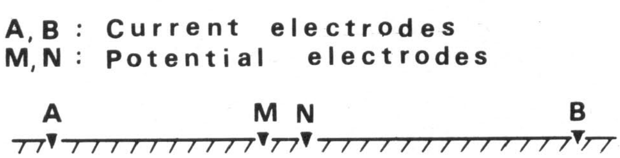

Fig. 1. The resistivity gradient array.

Similarity between resistivity gradient array data and other potential field data, i.e. gravity and magnetics, (Parasnis, 1967) immediately gives rise to the possibility of similar interpretation techniques. Consequently "Rule of Thumb" semi-quantitative interpretation methods can be devised just as they are for gravity and magnetic interpretation. As resistivity gradient array surveys are commonly used in base metal exploration, depth of burial of the ore body is the parameter of practical importance.

Grant and West (1965) treat the problem of the anomalous potential due to a sphere buried in a semi-infinite, homogeneous medium. Extension of their theory leads to the following expression for apparent resistivity:

$$P_a = P_1 \left[1 - 2a^3 \frac{(P_2 - P_1)(2x^2 - d^2)}{(2P_2 + P_1)(x^2 + d^2)^{5/2}}\right] \qquad (1)$$

where a is the radius of the sphere,
d is the depth of the centre of the sphere,
P_1 is the true resistivity of the surrounding medium,
P_2 is the true resistivity of the sphere,
and is subject to the condition $d > 1.3a$.

From equation (1) it can be shown that the depth to the centre of the sphere is given by:

$$d = 2.3\, x_{1/2} \qquad (2)$$

where $x_{1/2}$ is the "half-width" of the resistivity anomaly at half the anomaly amplitude (figure 2). Equation (2) constitutes a "rule of thumb" from which the approximate depth of burial of spherical-like bodies can be easily obtained.

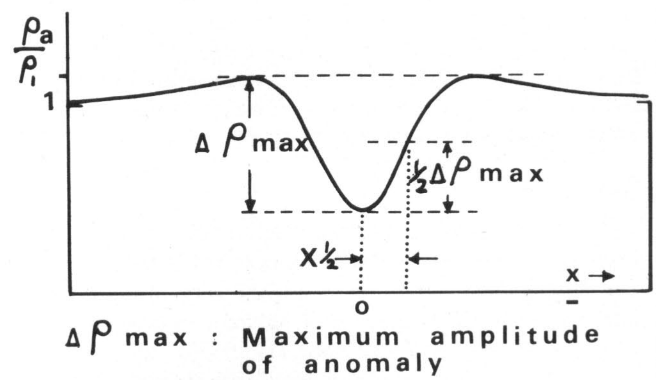

Fig. 2. Parameters involved in "rules of thumb" for spherical and cylindrical-like bodies.

Kunetz (1966) gives an expression for the potential due to a buried horizontal cylinder in a constant applied electric field. An expression for apparent resistivity based on this is:

$$P_a = P_1 \left[1 - 2a^2 \frac{(P_2 - P_1)(5x^2 - d^2)}{(P_2 + P_1)(x^2 + d^2)^2}\right] \qquad (3)$$

where the variables a, d, P_1 and P_2 are the same as for equation (1) and the condition $d > 1.3a$ still applies. The depth to the centre of the cylinder can be determined by

$$d = 2.2\, x_{1/2} \qquad (4)$$

where $x_{1/2}$ is the "half-width" as defined for equation 2 (figure 2). Equation (4) constitutes a "rule of thumb" interpretation for cylindrical-type bodies. Further, it is important to bear in mind that equation (2) and (4) are subject to the condition that the depth to the centre of these bodies must be greater than 1.3 times their radius. This restriction is necessary so that the boundary conditions at the surface of the earth are obeyed to sufficient accuracy (Grant and West, 1965; Lipskaya, 1949).

A major difficulty encountered in application of these "rules of thumb" is the detection of bodies at depths in excess of twice their radius. Figure 3 illustrates the response of a conducting sphere buried at 1.5 times and 2.0 times its radius. Van Nostrand (1953), treating this problem for Wenner array traversing, arrived at similar conclusions concerning the limiting depth at which a body may be resolved from its anomaly.

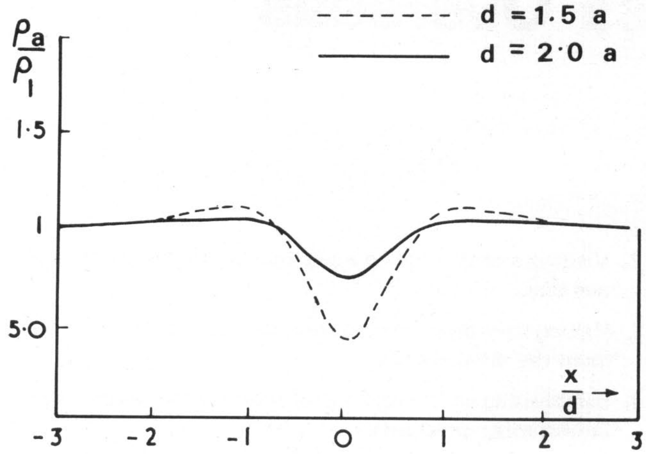

Fig. 3. Comparison of responses for spheres of depths 1.5 and 2.0 times their radii.

Further, it is important to note that a constant applied field assumption requires MN/AB to be approximately 1/100 or slighly more (figure 1)(Whiteley, 1974, pers. comm.). This condition is necessary because the potential electrode spacing required to be valid is a function of the geometry of the disturbing body, as will now be demonstrated.

In the case of a conductive sphere of unit radius, the anomaly due to an infinitesimal potential electrode spacing $\frac{dv}{dx}$ is

$$\frac{dv}{dx} = \frac{2\left(\frac{x_1 + x_2}{2}\right)^2 - d^2}{\left[\left(\frac{x_1 + x_2}{2}\right)^2 + d^2\right]^{5/2}}$$

while the anomaly due to a finite potential electrode spacing $\frac{\Delta v}{\Delta x}$ as measured in the field is

$$\frac{\Delta v}{\Delta x} = \left[\frac{x_2}{(x_2^2+d^2)^{3/2}} - \frac{x_1}{(x_1^2+d^2)^{3/2}}\right] \Bigg/ (x_2 - x_1)$$

where x_1 and x_2 are the locations of the potential electrodes a distance MN apart. If these are considered over the centre of the anomaly where $x_1 = -x_2 = MN/2$, then

$$\frac{dv}{dx} = \frac{-1}{d^3},$$

and

$$\frac{\Delta v}{\Delta x} = \frac{-1}{\left[\left(\frac{MN}{2}\right)^2 + d^2\right]^{3/2}}$$

The peak of the anomaly is clearly altered by MN spacings approaching the order of magnitude of the depth of the disturbing body. Hence caution must be exercised in choice of potential electrode spacing, since the amplitude of the apparent resistivity anomaly (upon which these rules are based) can be distorted significantly by inappropriate spacings.

Correct application of these simple "rules of thumb" allows good initial depth estimates to be made for spherical and cylindrical bodies from resistivity gradient array data.

Summary

The two "rules of thumb" presented are:

(i) d = 2.3 x½, (for spherical-like bodies).
(ii) d = 2.2 x½, (for cylindrical-like bodies).

References

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