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Depth determination of 2-D SP anomaly source using Energy Spectrum method and its advantages

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Summary

Self potential (SP) method is a passive method that involves measurements of naturally occurring potentials, commonly associated with the weathering of sulfides ore bodies. Energy spectrum (power spectrum) method developed primarily for gravity and magnetic data have been adapted to electrical SP data. In case of SP data analysis, energy is taken as the square of the Fourier amplitude spectrum which is directly proportional to the exponential of the depth of the causative source. From the energy spectrum, depth to the causative source can be estimated as half of the slope of the straight line of the spectrum. The spectrum method appears to have certain advantage over other methods like Euler and Tilt angle methods in the sense that it also gives the vertical extent of the causative ore body.

Introduction

Traditionally SP surveys have been very effective in mineral exploration by locating and delineating conductive mineral deposits existing under the oxidation-reduction conditions.

Origin of SP

SP is a passive method that employs measurements of naturally occurring electrical potentials commonly associated with the weathering of sulfide ore bodies. Measurable electrical potentials have also been observed in association with ground-water flow and certain biologic processes. The groundwater plays a key role by acting as an electrolyte.

The self-potential associated with an ore body is called its "mineralization potential." Self-potential (SP) anomalies across ore bodies are invariably negative, amounting usually to a few hundred mill volts. They are most commonly associated with sulfide ores, such as pyrite, pyrhotite, and chalcopyrite, but also with graphite and some metallic oxides.

Mechanism of SP

The most reasonable theory of this mineralization potential was proposed by Sato and Mooney (1960).

Self-potential depends on variations in oxidation (redox) potential with depth. The ground above the water table is more accessible to oxygen than the submersed part; an electrochemical reaction takes place at the surface between the ore body and the host rock above the water table. It results in reduction of the oxidized ions in the adjacent solution. An excess of negative ions appears above the water table. A simultaneous reaction between the submersed part of the ore body and the groundwater causes oxidation of the reduced ions present in the groundwater. This produces excess positive ions in the solution and liberates electrons at the surface of the ore body, which acts as a conductor connecting the two half-cells.

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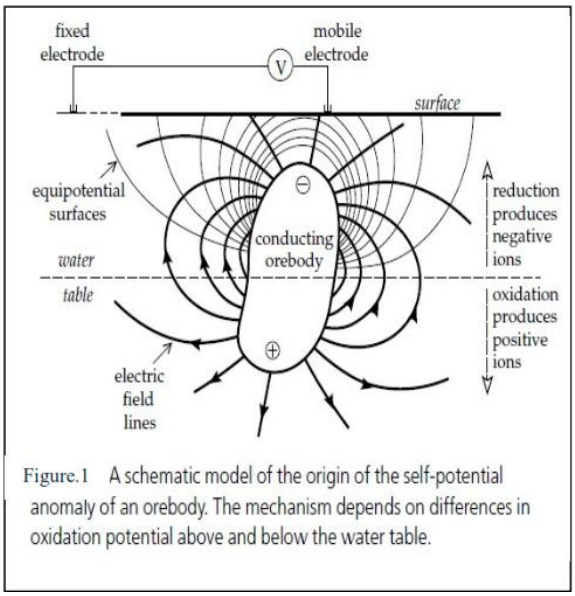

Figure.1 A schematic model of the origin of the self-potential anomaly of an orebody. The mechanism depends on differences in oxidation potential above and below the water table.

Potential difference between the upper and lower parts, causing a spontaneous electric polarization of the body.

Any geophysical prospecting work can be broadly classified into three stages on the basis of the nature of work involved, i.e. acquisition, processing and interpretation in that order. The acquisition of data involves measurements, based on specific physical property of rocks, over a generally randomly distributed observation points either along a profile or in two dimensional spaces. The density of observation depends upon the type of survey being a regional or detailed one. The raw data thus collected, has to be subjected to a few corrections especially with potential field measurement.

These reduced data sets are represented either in the form of a profile or a two dimensional map, from which, by an appropriate interpolation procedure, a set of data, suitable for various processing purposes can be obtained. Depending on the specific goal in mind, various processing scheme such as low pass filtering has selected.

After processing scheme the data set is ready for interpretation stage. For interpreting the data Energy spectrum is applied here.

Theory

Energy spectrum describes how the energy is distributed with the frequency. The applications of the Fourier transform to potential field data has gained increasing interest to a large number of geophysicists. The approach for determining the energy spectrum of the potential field has been under the assumptions of randomly distributed point masses throughout the infinite half space.

It is useful as a general rule to look at power spectra in one-dimensional or profile form rather than in two dimensional or map form.

Energy Spectrum is the square of the Fourier amplitude spectrum.

Forward Fourier transform,

$F(u, v) = 1/(2\pi) \iint f(x, y) \exp(-i(ux+vy))$

where,

x, y→ cartesian co-ordinate in space domain

u, v→ cartesian co-ordinate in frequency domain

Energy Spectrum, $E(u, v) = F(u, v)\ F^*(u.v)$

* represents the complex conjugate

$E(\omega) \approx K. \exp(-2z_0|\omega|)$

where,

z_0 is the depth of the causative body

K is the constant

ω is the angular frequency

The additive property of Power spectra is that logarithmic spectra are preferred for analysis.

Energy spectrum is directly proportional to exponential of depth. From the energy spectrum, depth to the causative source can be estimated as half of the slope of the straight line of the spectrum.

We have also used other two techniques: Tilt angle method and Euler method to compare the result of this method.

The tilt angle is defined as

$\theta = \tan^{-1}[(\partial V/\partial z)/(\partial V/\partial h)]$

Where,

$\partial V/\partial h = [(\partial V/\partial x)^2 + (\partial V/\partial y)^2]^{1/2}$

The magnitude of the total gradient is given by,
$|A| = [(\partial V/\partial x)^2 + (\partial V/\partial y)^2 + (\partial V/\partial z)]^{1/2}$

$\partial V/\partial h$, $\partial V/\partial z$ are the derivatives of the potential field in the resultant horizontal and vertical directions respectively

By Tilt angle method, we can determine the location and depth with high precision and also estimate the type of the causative source geometry by computing the structural index (SI)

For Euler method, Euler homogeneity equation of degree

(-N) is given by,
$(x - x0)\partial V/\partial x + (z - z0)\,\partial V/\partial z = -NV(x, z)$

The maximum peak frequency is given by,
Kmax = order of derivative x LX/ (depth of source x 2π)
Where, LX is the number of data points used in the FFT. This technique, though simple to use, requires a few modifications in analyzing the data based on the knowledge of the source geometry.

Case study

As a test case, we apply energy spectrum method to analyses the SP data acquired from Jhunjhunu district (Rajasthan).

Analysis of the power spectrum (Figure 2) suggests different ensemble polarization centers over the area on a 2D spectral analysis. The two depth segments determine 112ft and 34ft respectively. These are interpreted as the top and bottom of the polarisable body or it could just be that the first level is interpreted as the depth of the water table where the polarization just starts and the peak is attained with secondary enrichment with 112ft.

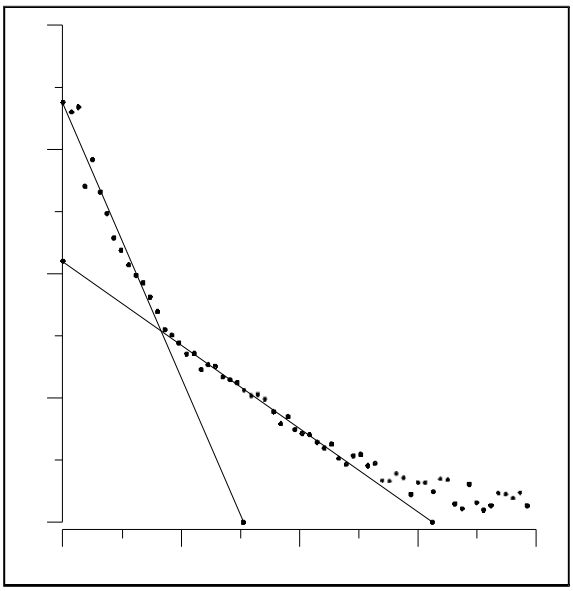

Figure 2: Energy spectrum of SP anomaly

From figure (3) we can observe that the maximum solution obtained by the Tilt angle method is 47.1% which is indicated by the pink circle lies between 50-55ft depth and about 26.2% solution which are indicated by blue lies between 55-60ft depths. We have got the solutions at the edges of the map which is due to the artifacts of the shallow feature.

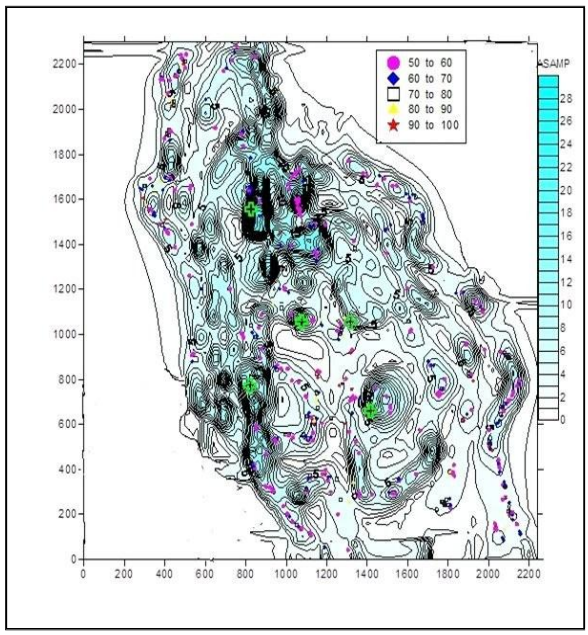

Figure 3: Tilt angle method applied on SP anomaly

Figure (4) shows solution obtained by the Euler method, where we can see that the maximum solution (60.5%) which is indicated by pink circle lies between 50-80ft depth. The close contour which is indicated by red zone which corresponds to maximum anomaly and the location of these zones will be the source of the causative body.

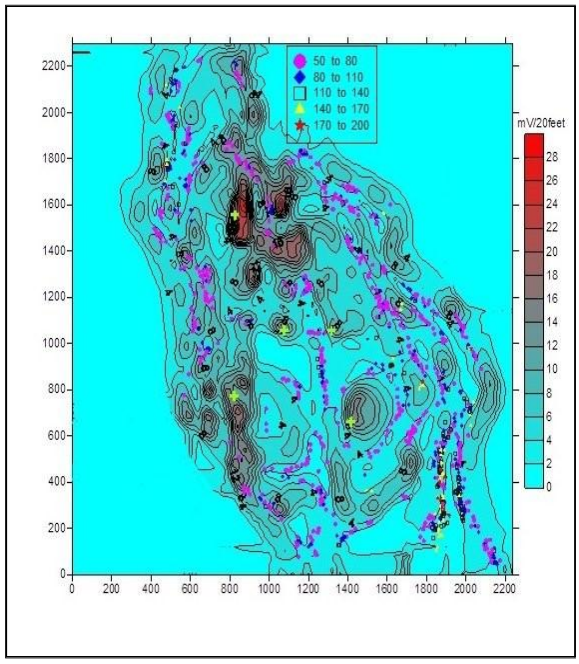

Figure 4: Euler method applied on SP anomaly

Conclusion

We have done a comparative study here by applying energy spectrum, tilt angle and Euler method. Energy spectrum reveals a depth of 45ft and at 112ft which correspond to the top and bottom of the causative source body. To check the validity of the proposed method we also use some other approaches like Euler and Tilt angle methods on the same data set which provides a depth of 50-60ft for the causative source conforming to the depth, obtained by spectrum method. The result are shown in the Fig. 2, Fig.3, and Fig.4 and also in tabulated form is given below.

Methods	Depths
Energy Spectrum	Shallow depth-34ft Deeper depth-112ft
Euler	50-55ft
Tilt angle	50-80ft

Table 1: Result of the calculated depths

However the spectrum method appears to have certain advantage over other methods in the sense that it also gives the vertical extent of the causative ore body. Our study suggests that two-dimensional spectral analysis can be gainfully applied to determine the depths and extent of the ore bodies.

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