PERGAMON

Computers & Geosciences 26 (2000) 847–852

COMPUTERS & GEOSCIENCES

Short Note

Visual interpretation of superposed self-potential anomalies in mineral exploration ☆

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Received 26 April 1999; received in revised form 14 January 2000; accepted 14 January 2000

1. Introduction

The self-potential method is employed widely to explore metallic-sulfide and graphite deposits [1]. Self-potential anomalies are shown to be useful to decipher the depth and polarisation angle of the target. Approximating the causative source to a physical model of simple geometric form (e.g. sphere, cylinder or sheet) usually carried out in the interpretation of self-potential anomalies, as in the situation for any potential field (Meiser, 1962; Paul, 1965; Bhattacharyya and Roy, 1981; Atchuta Rao et al., 1982; Atchuta Rao and Ram Babu, 1983; Satyanarayana Murthy and Haricharan, 1985). The parameters of the source model may be evaluated either by using the curve-matching technique or the method of characteristic curves. In the curve matching technique, the field curve is compared with sets of theoretical curves either manually or using a computer. On the other hand, it is possible to interpret self-potential data using computer methods (Ram Babu and Atchuta Rao, 1988; Jagannadha Rao et al., 1993) based on the Marquardt algorithm (Marquardt, 1963) or using spreadsheets in PC Microsoft Excel 5.0 [2].

Up to now, these interpretations of self-potential data were carried out only where the potential distribution was due to a single source model such as a sphere, cylinder or inclined sheet (Bhattacharyya and Roy, 1981; Satyanarayana Murthy and Haricharan, 1985; Ram Babu and Atchuta Rao, 1988; Jagannadha Rao et al., 1993). For the interpretation of self-potential anomalies the extreme values have been used, whereas the remaining values have been neglected.

In the situation of several disturbing ore bodies with their potentials superposed on one another, the previous methods are unsuccessful to evaluate self-potential anomalies and it is possible to make an interpretation just by picking out a few measurement points. Such anomalies with superposed potentials could be measured throughout the mineralised areas with active tectonics.

In this paper, a scheme for visual interpretation of superposed self-potential anomalies over the many-source models in the form of spheres, horizontal cylinders or inclined sheets is developed and a FORTRAN program, which is easy to use for the interpretation of self-potential data, is written for IBM-compatible computers. The program with the name SPINTERP is created for self-potential data obtained in areas with metallic-sulfide and graphite deposits.

2. Self-potential anomalies caused by simple geometric models

Consider either a polarised sphere (or a horizontal cylinder) embedded in a homogeneous one-half space. The self-potential anomaly $V(x)$ caused by a sphere or a cylinder in a homogeneous half-space (Fig. 1) at any point, $P(x)$ along the principal profile is given by

☆ Code available at http://www.iamg.org/CGEditor/index.htm

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PII: S0098-3004(00)00012-1

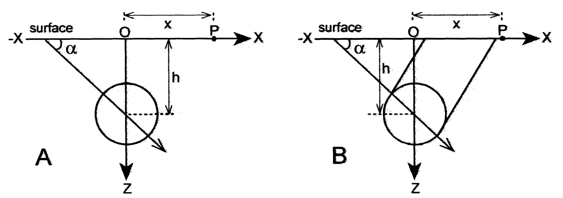

Fig. 1. (A) Parameters for buried sphere model. (B) Parameters for buried infinite horizontal cylinder model.

Bhattacharyya and Roy (1981) as follows:

$$V(x) = M \cdot \frac{x\cos\alpha - h\sin\alpha}{(x^2+h^2)^p} \quad (1)$$

where M is the electric dipole moment, h is the depth to the centre of the sphere or cylinder. The axis of the (infinite) cylinder is parallel to the Y-axis. In Eq. (1) $p = 1$ for the horizontal cylinder and $p = 3/2$ for the sphere, α is the polarisation angle measured from the surface (X-line) to the polarisation axis lying from the centre of the sphere or cylinder to the surface. The point O is on the surface at a point vertically above the centre of the body. The parameter x is the distance from the point O to P. When α is equal to 90°, the theoretical anomaly calculated using Eq. (1) has a symmetrical pattern.

Similarly, the anomaly generated by an ore body of two-dimensional sheet form (Fig. 2) at any point $P(x)$ along the principal profile is given by Atchuta Rao and Ram Babu (1983) as follows:

$$V(x) = M \cdot \log_e \frac{x^2+h^2}{(x-a)^2+H^2} \quad (2)$$

where the h and H are the depths to the upper and lower edges of the sheet, respectively. The inclined sheet-like ore body of length $2A$ units extending infinitely along its strike has a dip angle α. In any X-Y-Z Cartesian coordinate system the coordinate origin O is placed directly over the strike of the sheet, and the Z-axis is vertically downward. The dip angle α of the sheet is measured clockwise from the positive X-axis. When α is equal to 90°, the maximum lies immediately above the top of the sheet.

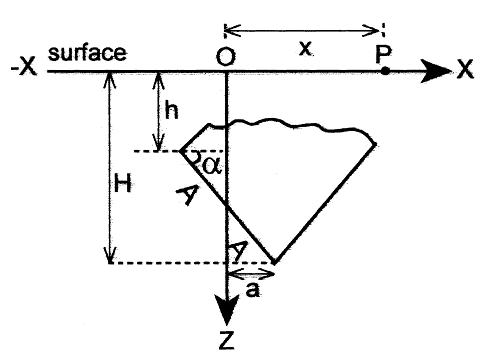

Fig. 2. Parameters for inclined sheet model.

3. Overview of program and interpretation scheme

The program SPINTERP allows a superposed self-potential anomaly to be interpreted using a modelling technique based on simple geometric models. It was compiled using Microsoft Fortran Version 5.0. The software SPINTERP is a menu-driven and easy to use program that runs under the DOS system with minimum hardware requirements. During the interpretation, it is possible to select many different models (i.e. sphere, cylinder or inclined sheet) throughout the superposed self-potential anomaly. This program differs from other computer methods (Ram Babu and Atchuta Rao, 1988; Jagannadha Rao et al., 1993) that are designed as an inversion scheme employing the Marquardt algorithm (Marquardt, 1963). It is simple since it uses only forward modelling for the interpretation.

In the first step of the visual interpretation procedure, the program SPINTERP requires a data file having the observed field self-potential data, (millivolts versus the distance X) to be analysed. The program displays the field anomaly on screen when the reading is completed. It allows the choice of three different simple models (sphere, cylinder or sheet) at any point on the survey line (X-axis), localised using a moving arrow by the program user. This arrow can be moved easily by pressing the left or right cursor keys. During this procedure the program informs the location value (X-distance) of the arrow. When the necessary parameters of the desired model (Figs. 1 and 2) for the selected point are entered using the keyboard, the synthetic self-potential anomaly produced by the software (from Eq. (1) or (2)) is drawn on the previous screen with a curve of a different colour. Other models can be selected beneath the new locations on the profile of this anomaly and then their parameters can be entered in to the program using a similar manner followed for the first model.

Once the model parameters are entered, the total synthetic curve is re-calculated (updated) and re-displayed, superposed on the previous model's anomaly curve obtained with different parameters. This visual interpretation process is continued until a synthetic curve more closely plausible with the actual (field) anomaly is obtained.

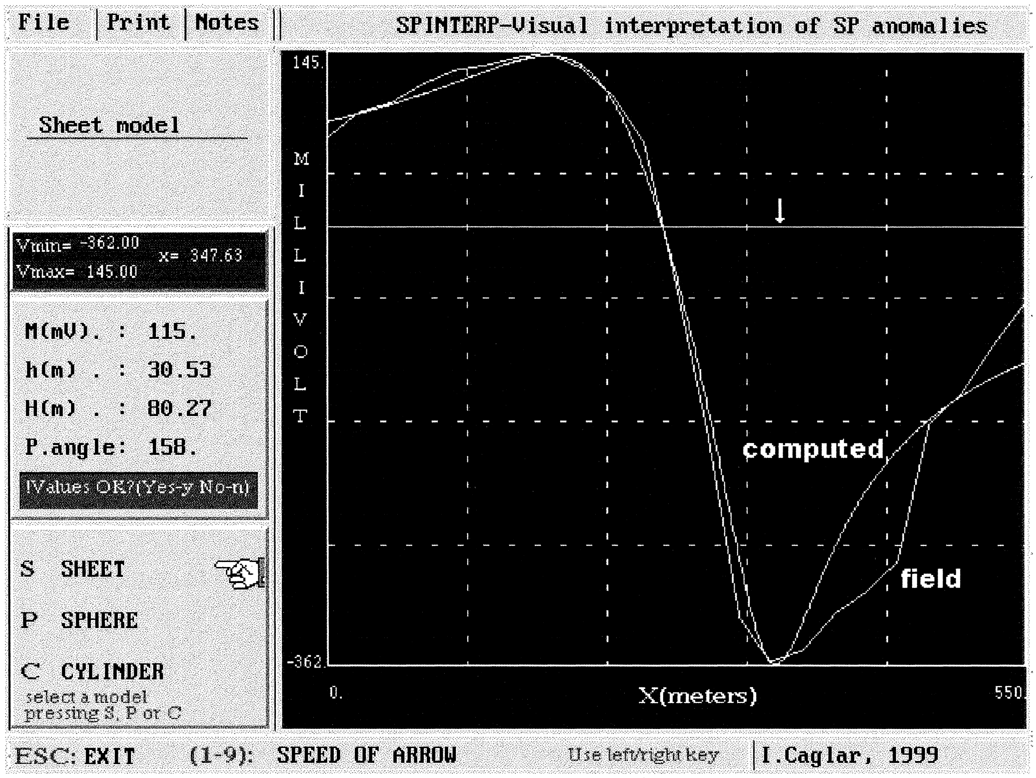

Fig. 3. Display screen of test result of visual interpretation applied to self-potential anomaly measured over single sheet-like graphite body (anomaly after Semenov, 1968).

4. Example applications

4.1. Test example

Application of the visual interpretation by SPINTERP is demonstrated on a well-known anomaly that is caused by a sheet-like graphite body (Semenov, 1968) to test scaling and computation features of the program, (Fig. 3). The values of the model parameters of this anomaly obtained by the nomogram method were taken from Satyanarayana Murthy and Haricharan (1985; Table 2) and converted for the inclined-sheet model shown in Fig. 2 (Table 1). The new values (Table 1) are then entered in to SPINTERP for a single sheet. Fig. 3, indicates a good agreement between the field and computed (synthetic) anomaly.

4.2. Example 1

Fig. 4 shows a field self-potential anomaly displayed by the program, taken from a metallic-sulfide mineralisation area in Boyali, northwestern Anatolia. Several

Table 1
Interpretation of self-potential profile over sheet-like graphite body (anomaly profile after Semenov, 1968), comparison of results. Parameters given by Satyanarayana Murthy and Haricharan (1985, fig. 1) are: L = distance of origin from zero anomaly; d = depth to center of sheet-like body; θ = angle of polarisation (degrees). Values of M are always considered as negative sign by SPINTERP

Parameter	Method of Satyanarayana Murthy and Haricharan (1985)	Values converted for Fig. 2	Used in Fig. 3
X(m)	(L = 22.4)	343.9	348
M(mV)	130	130	115
h(m)	(d = 55.4)	30.53	30.53
H(m)	–	80.27	80.27
α(°)	(θ = 22°)	158	158

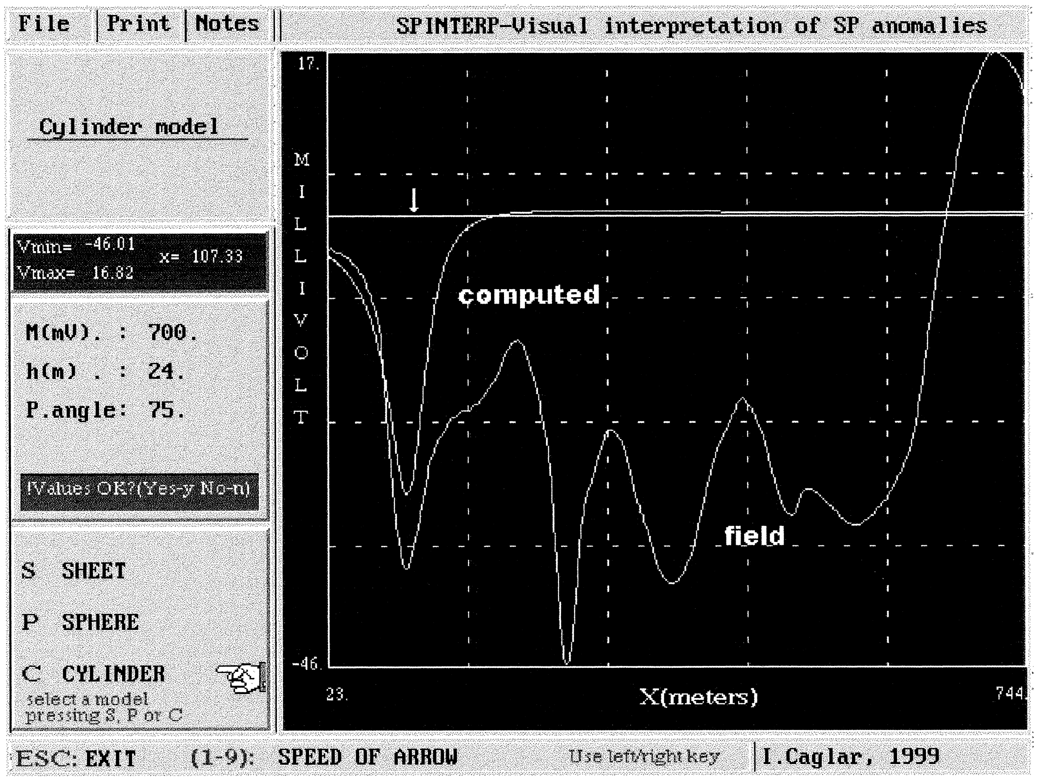

Fig. 4. Model entry and graphical display screen showing self-potential field anomaly of Boyali area. Synthetic curve obtained for left portion of profile is associated with single cylinder model. Its parameters are displayed within interpretation box.

metallic-sulfide bodies (pyrite, chalcopyrite and galenite) with different sizes and shapes cause it. Therefore, it is not possible to make a quantitative interpretation, picking out extreme values of the anomaly by using master curves, nomograms or computer methods (Bhattacharyya and Roy, 1981; Ram Babu and Atchuta Rao, 1988; Jagannadha Rao et al., 1993). Over this self-potential profile several simple geometric models are selected and their parameters are entered in to the program starting at the left side of the profile.

The origins of the bodies with a simple shape could be estimated by looking at theoretical curve groups

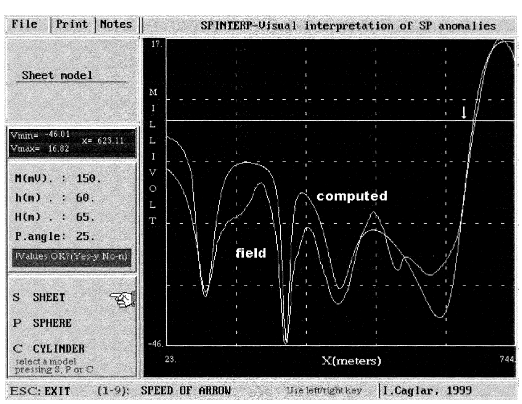

Fig. 5. Display screen of final result in visual interpretation of Boyali anomaly. Field and computed (model) curves are in good agreement.

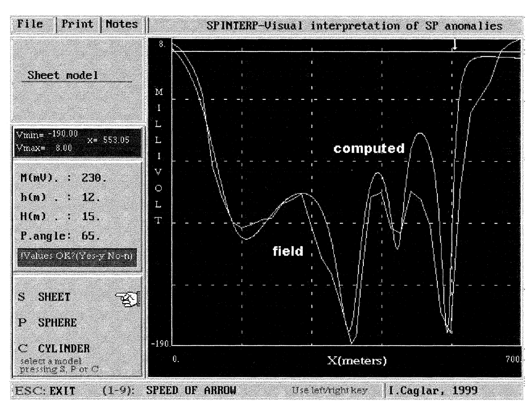

Fig. 6. Display screen of final step in visual interpretation of self-potential anomaly measured over graphite deposits. Field data are taken from Meiser (1962).

Table 2
Final result of interpretation of self-potential anomaly over Boyali ore-bodies (Fig. 5)

Body	*X*(m)	*M*(mV)	*h*(m)	*H*(m)	α(°)
Cylinder	107	700	24	–	75
Sphere	270	200	12	–	90
Cylinder	381	750	35	–	90
Sheet	623	150	60	65	25

calculated for the various models. On the other hand, the selection of the model depends on the geological framework of the area and the anomaly contour map. If the anomaly contours in the map are elongated, either the cylinder or the sheet model may be adequate. In our example, a cylindrical model is first created beneath the point $X = 107.33$ m, along a survey profile, to interpret the initial part of the field anomaly. The necessary parameters of the models are entered and changed, until an approximate agreement between the pattern of field and synthetic curve is obtained.

In each step, the model parameters are chosen prudently, because the amplitude of each single anomaly may be increased at the end of the interpretation, when the presumed total synthetic curve is obtained. When an acceptable relationship between both curves, computed and field, is visually observed (Fig. 4) after several attempts, the interpretation of this part of the anomaly is accomplished. Then the remaining parts of the anomaly are visually interpreted following the same procedure applied to the left side of field data. Fig. 5 shows the graphical final result, and the numerical results are given in Table 2.

4.3. Example 2

The self-potential anomaly over a graphite area given by Meiser (1962; fig. 10) is considered in the second example. A few high amplitudes with a negative sign are observed in this anomaly where the potential of several disturbing bodies are superposed upon each other.

Following the approximate geological section of this profile that is given by Meiser (1962), placing four sheet models in the subsurface completes the interpretation. The field anomaly and calculated total synthetic anomaly (Fig. 6) and their parameters (Table 3) are in approximate agreement with Meiser's (1962) results.

Table 3
Final result of interpretation of self-potential anomaly over graphite ore-bodies given by Meiser (1962, fig. 10). Inclined-sheet model is used for all bodies (Fig. 6)

Body	*X*(m)	*M*(mV)	*h*(m)	*H*(m)	α(°)
1	115	380	80	90	135
2	359	200	27	37	70
3	453	180	18	23	75
4	553	230	12	17	65

5. Summary and conclusions

Although the curve matching, nomogram and previous computer methods are useful if the self-potential anomaly is not complex and it is assumed to be caused by only a single ore-body, these methods are unsuitable for the interpretation of the superposed self-potential anomalies. The program SPINTERP many bodies to be placed closely together in the subsurface which is not possible using older methods.

Forward modelling of simple models (e.g. sphere, cylinder and sheet) can be performed using this software to obtain the sets of typical curve groups for various values of the parameters (such as M, h, H and α). It is useful both for geoscientists performing mineral exploration work and for teaching purposes. A compiled version of the program and test data sets are available from the IAMG serve.

Acknowledgements

The author thanks Ismail Aksu, for his keen interest in this work. This study was supported by the Scientific and Technical Council of Turkey (TUBITAK) grant YDABÇAG-0236G (coordinated by N. Görür) and by the Research Foundation of Istanbul Technical University grant ITU-727.

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