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LABORATORY HLEM RESPONSE OF ELLIPSE MODELS

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Volcano sedimentary stratiform massive sulphide deposits of lenticular form are simulated by metallic ellipse models in the laboratory. Their HLEM profiles are similar in shape to those of the half-planes but smaller in amplitude. If EM anomalies of ellipses are interpreted using Argand diagrams prepared for half-planes, tabloids and ribbon models, they will give higher depth and lower induction number than their true values. Argand diagrams for vertical and horizontal ellipses are presented in the paper.

Depósito de sulfetos maciços lenticulares em sedimentos estratificados de origem vulcânica, foram simulados no laboratório por modelos metálicos de forma elíptica. Os seus perfis HLEM tem forma semelhante àqueles de semi-planos, porém com menores amplitudes. Se as anomalias EM de elipses forem interpretadas, usando diagramas de Argand preparados para semi-planos, tablóides e modelos de tiras, o resultado indicará maior profundidade e menor número de indução do que seus valores reais. Os diagramas de Argand para as elipses horizontais e verticais são apresentados nos casos estudados.

INTRODUCTION

Volcano-sedimentary stratiform massive sulphide deposits are generally limited in strike and depth extent in comparison to the coil separation (L = 50 m to 150 m) used in their EM prospecting. Kanehira & Tatsumi (1970), Lambert & Sato (1974) have reported the dimensions of Kuroko sulphide deposits in the Hokuruku District, Japan. Often the extension of the ore body in the strike direction is more than the depth extent; and its thickness is several times smaller than the other two dimensions (Sangster & Scott, 1976). Unmetamorphosed deposits, with some exceptions, are roughly tabular or lenticular in form, pinching in the strike direction particularly those occuring in massive volcanic rocks. Therefore, conducting massive sulphide deposits of limited size can be represented in EM model studies by thin tabloids, disks and ellipses.

Scale model EM response of a conducting disk in a uniform inducing field was studied by Bruckshaw (1936). Ward et al. (1968) computed tilt angle profiles, also of a disk, in a uniform field and constructed intepretation diagrams to estimate its dip, depth of burial, radius and conductivity-thickness product from AFMAG data. Douloff (1961) computed EM response of vertical and horizontal disk of infinite conductivity in a dipole field. He also carried out scale model experiments to check the theoretical curves and produced type curves for the finitely conducting disk energized by a HLEM and Canadian airborn EM system. Verma & Gaur (1975) studied the response of a variously dipping graphite slab of limited depth extent in air and in a conducting solution, to horizontal coplanar, vertical coaxial, vertical coplanar and rotary field coil systems. They found an enhancement in the anomalies and the loss of asymmetry in the profiles of dipping models due to the conducting host. Jones & Wong (1975) reported the scale model responses of a long vertical tabloid and flat lying ribbon conductors to a dipole-dipole prospecting system. They studied both horizontal and vertical components of the EM response.

Scale model EM response of thin horizontal and vertical elliptical conductors to a HLEM system is studied in this paper.

ELECTROMAGNETIC SCALE MODELING

The theory of electromagnetic similitude for modeling has been amply discussed by Sinclair (1948) and subsequently presented by Grant & West (1965), Ward (1967) and Frischknecht (1971), among others. Half-plane response to a dipole-dipole system can be simulated in the laboratory at a reduced scale by conserving the induction number $\mu\omega\sigma Lt$, where μ is the magnetic permeability, ω the angular frequency, σ the electrical conductivity, L the separation between the transmitter and the receiver coils and t the thickness of the sheet. According to Frischknecht (1971) the response, even near the edge of a finite sheet, depends on the parameter involving the product of the conductivity, the thickness and one other dimension, L. Therefore, the parameter $\mu\omega\sigma tL$ is used here to calculate the response parameter of the ellipse models as well.

EXPERIMENTAL PROCEDURE

The equipment used for carrying out the experiments consists of a) a framework of the geometrical model, the transmitting-receiving coils and the conductor (ore-body); b) a transmitting system consisting of a transmitting coil fed by an oscillator, and c) a phase detecting system to analyse the phase and amplitude of the e.m.f. induced by the secondary field in the receiver coil. The inphase and quadrature components, normalised to the primary field are then registered on a graphic chart recorder. Fig. 1 shows schematically the part (b) and (c) of the equipment.

The ellipse models were prepared from metal sheets of aluminium, copper and brass of varying thicknesses. Physical details of the scale models are given in Table 1. The values of electrical conductivities of the sheets given here are as reported by the manufacturers. These conductivities, at a scale factor of 500 correspond to the conductivities of typical sulphide ore minerals (Parasnis, 1956).

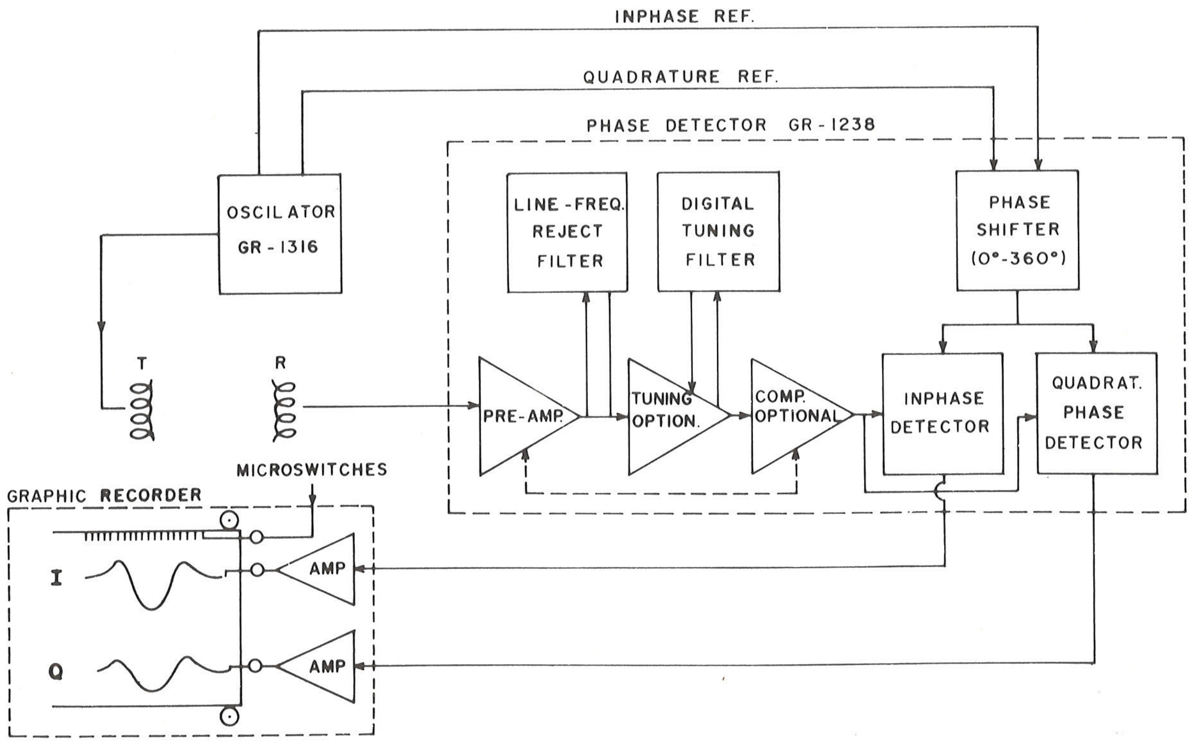

Figure 1 – Schematic diagram of the transmitter, receiver and the phase detector.

The reference signals from the oscillator were calibrated for phase and amplitude in relation to the e.m.f. induced in the receiving coil due to the primary field, in the absence of the model. This was accomplished by setting the 0-360° phase-shifter and sensitivity of the meters as well as that of the graphic chart recorder such that the inphase reads 1 and the quadrature 0. The amplitude scale of the quadrature component was calibrated by shifting the phase by 90° and adjusting the quadrature component to read 1 and inphase as 0. The phase switch was then returned to its former position. The recording pens for both the inphase and quadrature components were then positioned in the centre of the graphic chart through biasing-base potentiometers. This permitted recording of both positive as well as negative anomalies. The ellipse models were then placed at the predetermined positions and the EM profile recorded by making the cart containing the T-R system run on the rails with the help of a stepper motor. The cart actioned microswitches fixed on the rails to provide positioning marks on the chart. The profiles were orthogonal to the major axis of the ellipse models. The traverses were principle profiles (normal and across strike at centre) except when mentioned otherwise.

ANALYSIS OF RESULTS

EM Profiles of Vertical and Horizontal Ellipses

Fig. 2 demostrates typical EM profiles of vertical and horizontal ellipses obtained with a horizontal coplanar coil system. Horizontal ellipse profiles show two negative peaks with a central hump, similar to a horizontal ribbon profile. Also, the vertical ellipse profiles are similar to that of a vertical half-plane or a tabloid. Quantitatively, however, peak-to-peak inphase anomalies of the vertical ellipse are much less than those of half-planes and tabloids. On the other hand the quadrature anomaly is equal to that of a tabloid and a little more than that of a vertical half-plane (Fig. 3). Similar results are obtained also for horizontal ellipse models in our study compared to the anomalies of horizontal strips obtained by Jones & Wong (1975).

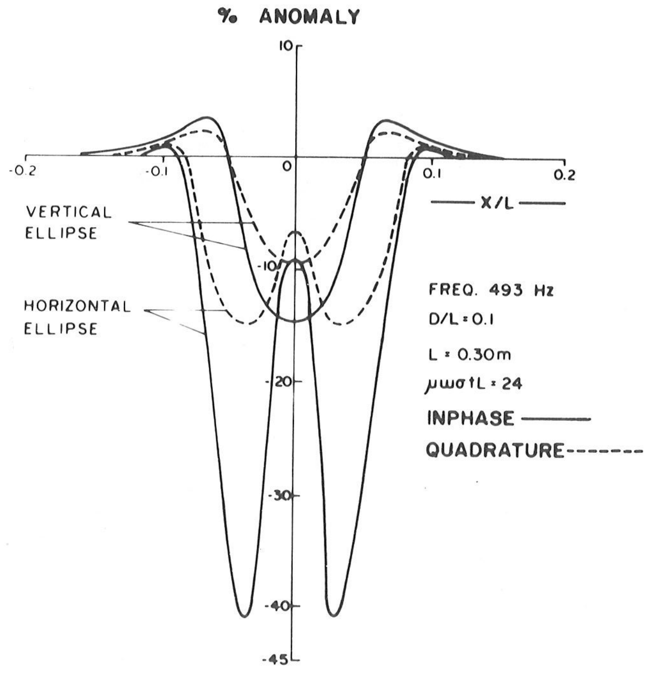

Figure 2 – Comparative study of the vertical and horizontal ellipse profiles. The traverses are across strike at centre.

Table 1 – Physical details of the ellipse models.

Material	Electrical Conductivity	Thickness	Conductivity x Thickness	Model Parameter $\sigma = \mu\omega\sigma tL$				
	$\sigma(10^7 S/m)$	$t(10^{-3}m)$	$\sigma t(10^4 S)$	f = 293Hz	493Hz	793Hz	1270Hz	1870Hz
Brass	1,9	1,15	2,19	15,2	25,5	41	65,7	96,8
Aluminium	3,8	0,54	2,05	14,2	24	38,5	61,7	90,9
		1,02	3,88	27,0	45,2	72,8	116,6	171,7
		1,52	5,78	40,1	67,5	108,5	173,8	255,8
Copper	5,8	0,51	2,96	20,5	34,5	55,6	89,0	131,0
		1,16	6,73	46,7	78,6	126,4	202,4	298,0
		1,64	9,51	66,0	111,1	178,7	286,2	421,3

$\mu = 4\pi \times 10^{-7}$ H/m, L = 0,30 m
Major axis of the ellipses, 2a = 0,556 m
Minor axis of the ellipses, 2b = 0,25 m
Eccentricity, e = 0,9

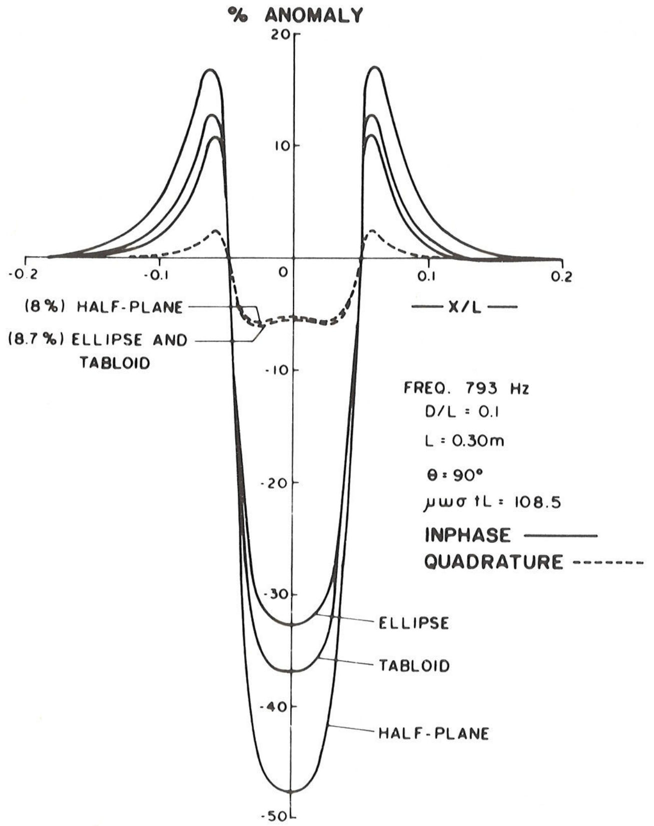

Figure 3 – Comparative study of the EM anomalies due to a half-plane, a tabloid and an ellipse model, all cut from the same aluminium sheet, θ=90. The traverses are across strike at centre.

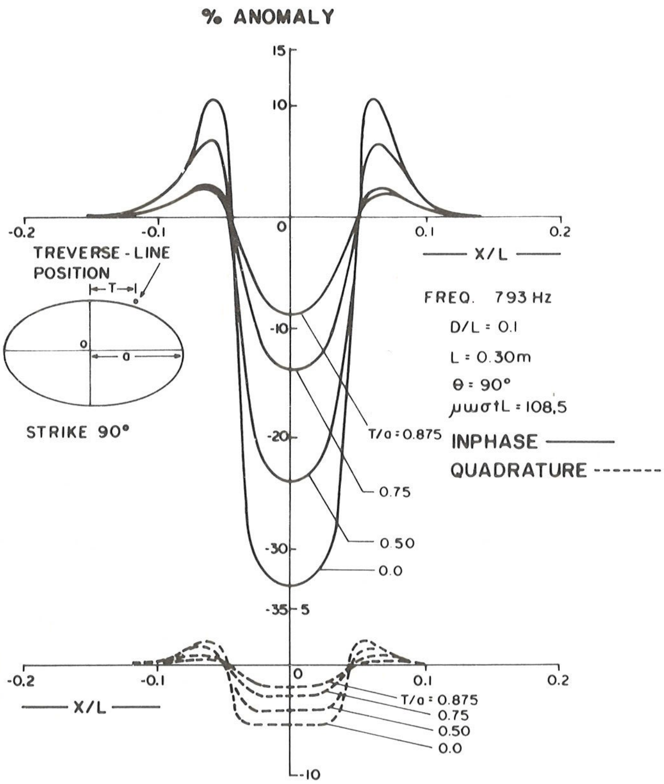

Figure 4 – Changes in the EM anomalies due to traverse line off-set in relation to the epicentre of the ellipse. The traverses are across strike of the ellipse.

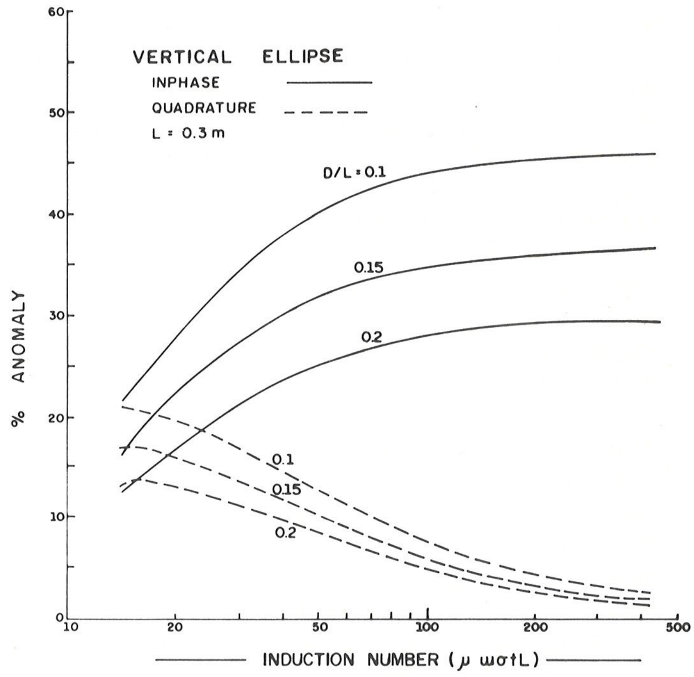

Figure 5 – Anomaly variation with induction number of a vertical ellipse at different dephs of burial.

Effect of the Traverse Line Off-set

As the anomaly shapes of the ellipse models are similar to flat-lying ribbons, vertical tabloids or half-planes, they can not be distinguished from each other on the basis of profiles. Since ribbon, tabloid and half-plane models are considered infinite in the strike direction, any displacement of the traverse line along the strike should not change the anomaly. On the other hand the ellipse being of limited extent in strike as well as in its dimensions, any dislocation of the traverse line along the strike direction would substantially change the anomaly amplitudes. Fig. 4 shows this effect. In case of steeply dipping ellipses, the depth to the upper edge of the model also varies in the strike direction.

Anomaly Index Diagrams

To study the variation of inphase and quadrature anomalies with the induction number of the ellipse models (μωσtl), peak-to-peak anomalies for different depths are plotted in Figs. 5 and 6. Horizontal ellipse anomalies are much larger compared to those of the vertical ellipses. Also, the anomalies of horizontal ellipses reach saturation much earlier than the vertical ellipses as the induction number is increased. On the other hand, horizontal ellipse anomalies decrease much more rapidly with the increasing depth than the vertical ellipse anomalies.

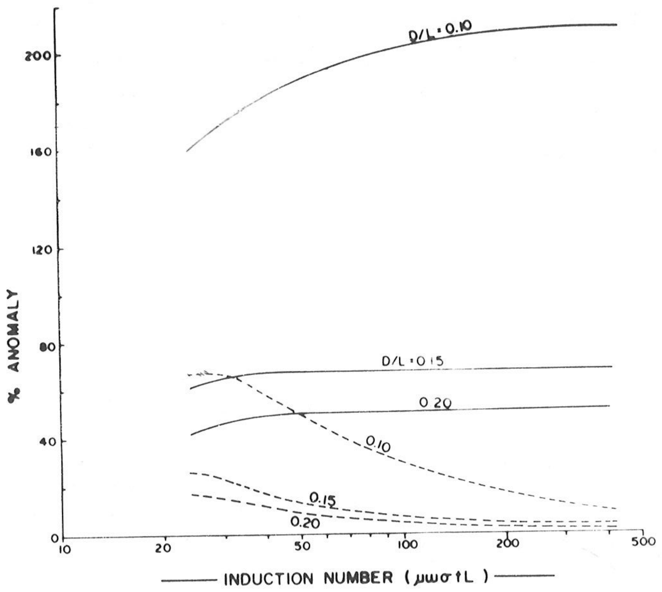

Figure 6 – Anomaly variation with the induction number of a horizontal ellipse at different depths of burial.

CONCLUSIONS

Tabular and lenticular shape sulphide bodies of limited spatial extent yield smaller EM anomalies compared to those produced by the bodies infinite in strike and depth extent. Therefore, interpreting anomalies due to bodies of limited size using the Argand diagrams prepared for half-planes, tabloids and ribbon models will result in higher depth and lower σt product (due to the low I/Q index for ellipses) than their true values. Thus, when EM

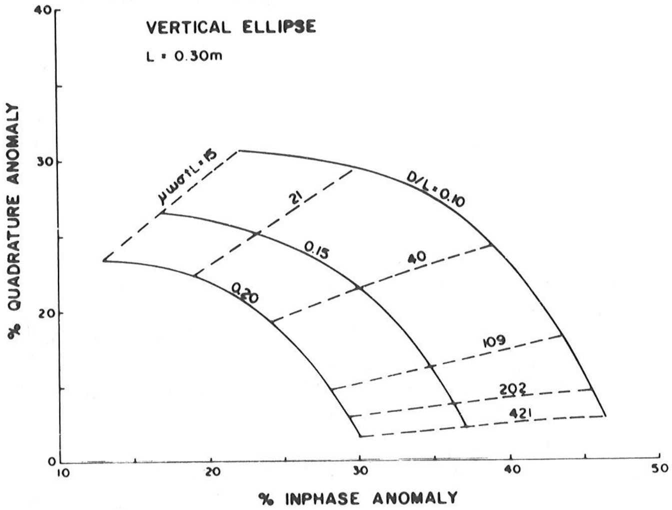

Figure 7 – Anomaly index diagram for a vertical ellipse.

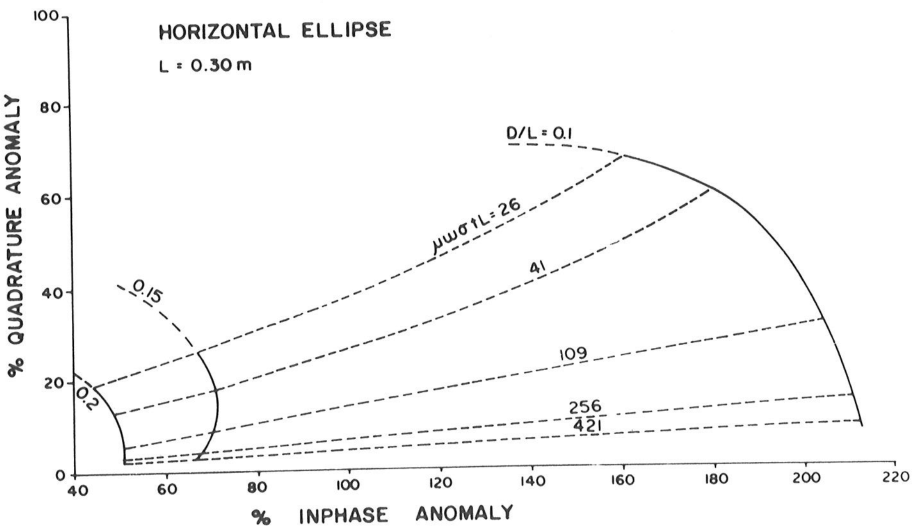

Figure 8 – Anomaly index diagram for a horizontal ellipse.

prospecting for sulphide bodies one should first decipher their shape and areal extent relative to the separation between T-R coils (L) through profiling and mapping. This would help in deciding whether the target could be considered of infinite extent or not. In case of elliptical bodies appropriate Argand diagrams should be used. As these diagrams for ellipse models are not yet available in the literature, they are presented here in Figs. 7 and 8 for vertical and horizontal ellipses. However, it is recommended that such diagrams be prepared for dipping models of varying ellipticity and sizes. Horizontal ellipse anomalies chould be used in the interpretation of EM anomalies due to clay lenses and perched ground water bodies or a conducting overburden of limited extent.

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REFERENCES

BRUCKSHAW, J. McG. – 1936 – Experiments on conducting laminae in periodic magnetic fields. Proc. Phys. Soc., **48**:63-73.

DOULOFF, A.A. – 1961 – The response of a disk in a dipole field. Geophysics, **26**:452-464.

FRISCHKNECHT, F.C. – 1971 – Electromagnetic scale modeling. In: Electromagnetic probing in geophysics. Boulder, Golem press: 265- 320.

GRANT, F.S. & WEST, G.F. – 1965 – Interpretation theory in Applied Geophysics. New York, McGraw-Hill Book Company: P. 581.

JONES, B. & WONG, J. – 1975 – Some thin sheet responses to a model dipole-dipole prospecting system. Geoexploration, **13**:187-196.

KANEHIRA, K. & TATSUMI, T. – 1970 – Bedded cupriferous iron sulphide deposits in Japan – a review. In: Volcanism and ore genesis (T. Tatsumi, ed.), Tokyo, Univ. Tokyo Press: 51-76.

LAMBERT, I.B. & SATO, T. – 1974 – The kuroko and associated ore deposits of Japan: A review of their features and metallogenesis. Economic Geology, **69**:1215-1236.

PARASNIS, D.S. – 1956 – The electrical resistivity of some sulphide and oxide minerals and their ores. Geophys. Prospect., **4**:249-278.

SANGSTER, D.F. & SCOTT, S.D. – 1976 – Precambrian, stratabound, massive Cu-Zn-Pb sulphide ores of North America. In: Handbook of strata-bound and stratiform ore deposits (K.H. Wolf, ed.), Elsevier, Amsterdam, **6**:129-222.

SINCLAIR, G. – 1948 – Theory of models of electromagnetic systems. Proceeding I.R.E., **36**:1364-1370.

VERMA, O.P. & GAUR, V.K. – 1975 – Transformation of eletromagnetic anomalies brought about by a conducting host rock. Geophysics, **40**:473-489.

WARD, S.H. – 1967 – The electromagnetic method. In: Mining Geophysics, Tulsa, S.E.G., **2**:224-372.

WARD, S.H., O'BRIEN, D.P. & PARRY, J.R. – 1968 – AFMAG – Interpretation. Geophysics, **33**:621-644.

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