American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)
ISSN (Print) 2313-4410, ISSN (Online) 2313-4402

http://asrjetsjournal.org/

Some Aspect Dealing with VLF.EM Field Measurements

Mohammad Ibrahim Abdul-Razzak*

Ministry of Water Resources, National Center for Water Resources Management, Groundwater Studies Department
Email: moha19562003@yahoo.com

Abstract

During the VLF.EM survey to trace and map the delineation of the Cleveland dyke near Whitby / England, some interesting features dealing with the resultant VLF.EM anomalies as the shape of the Real profile and their cross-over point were observed and indicated. A reliable and aid solution was given by using some other geophysical method which carried in the same site as electrical resistivity technique (involving Wenner array) with geological information available in the area under investigation. The dyke was successfully traced and its delineation in NE-SW direction indicated. The parameters regarding such concealed body as location, depth, dip and its direction were calculated and given as well. The VLF.EM method has been revealed their efficacy to locate such high resistive concealed dyke.

Keywords: Geophysics ; VLF-EM; Dyke Investigation.

1. Introduction

The idea of using radio signals for EM prospecting is not new and efforts have been made in North America, in Europe and in Russia to use the radiofrequency methods for ore prospecting. Despite these and other activities, radiofrequencies methods were not accepted for exploration until Geonics Limited introduced the first instrument working in the VLF range (15-25 khz) in 1964. Since then the VLF.EM method has established its usefulness in mineral prospecting, geological mapping, ground water investigation, land slide and subsurface pollution monitoring studies [12, 14, 16, 21 ,23 and 24]. It has also been proved as a successful tool for locating faults, mineralized zones and different geological structure. Further more, it is found considerably faster, cheaper and more reliable in comparison with IP, electric and horizontal loop EM methods [17, 2, 5, 6 and 3].

---

* Corresponding author.

But the main and the greatest advantage of this method are due to the fact that the survey work can be undertaken by a single operator [6]. Besides all the above advantages it has another useful application in areas of highly resistive surface formations.

When the input horizontal primary EM field is presented and a conductive body encountered in homogeneous ground, an induced secondary magnetic field will be generated and the combined primary and secondary field of equal frequency but differing in amplitude, phase and direction produces an elliptically polarized field. This polarization field is used for distinguishing the heterogeneous electric zone that may often be associated with the presence of geologic faults, contacts, mineralized fissures, brecciated and clay zones and conductive overburden [17, 2, 6, 7, 9 and 20].

As the application of VLF.EM increased, modeling has been developed either numerically or physically to further understand the effect of some parameters on the VLF.EM anomalies [8].

A quantitative interpretation of the VLF.EM anomaly has been given numerically by [13, 22 and 18] whereas this has been given experimentally by [10, 8 and 4]. The depth and dip was the main target in these interpretations.

2. Location and Geology of the Area

The main investigated area, equal to (25,000 m^2) is located about 9km south west of Whitby in North Yorkshire and about 500m to the east of Pickering-Whitby road. The flatness is the most characteristic feature of the topography in the investigated area, (Figure 1).

The sedimentary geology of the area under investigation is centered on the upper Estuarian series of Jurrasic age. This consists of nearly horizontal bands of sandstone, calcareous shale, calcareous sandstone and limestone of varying thickness. Such sequence has been intruded by the Tertiary igneous Cleveland dyke of tholiite or augite-andesite which consists of augite, quartz, pyrite, rare apatite and biotite with some percent content of magnetite (4%). The width and level to its upper surface is very variable, ranging from (2-25m) and from (3-10m) respectively. Recent erosion and deposition has exposed the dyke in some places or covered it with drift in others [19].

However, this dyke has been extensively quarried and also mined to a considerable depth in some localities, for use as a road stone.

3. The VLF.EM Method

The VLF.EM method utilizes the source of electromagnetic radiation generated in the low frequency band of (15-25khz) by the powerful radio transmitter stations situated conveniently around the world and transmitting continuously either un-modulated carrier waves or a wave with superimposed morse code. Their fields of coverage usually overlap substantially and produce choice of different frequencies in any exploration survey [15].

The radiation from the transmitter has two components; the electric component lies in the vertical plane and the magnetic component lies at right angle to the propagation direction in a horizontal plane, (Figure 2a) [1]. The magnetic component is the main one used in the exploration, because it carries the bulk of the signal energy, and it offers certain advantages in practical field measurements [15].

The magnetic field lines are horizontal circles around the antenna, and at large distances from the source, the field is essentially horizontal and practically uniform. If, any conductor lies in the path of the horizontal magnetic field, a secondary electric current is generated which tends to flow in the conductor. The magnitude of induced electric currents will depend on the electrical properties of the conductor and its attitude to the primary field [7, 1].

Consequently, a secondary magnetic field will produced associated with the conductor, which is usually out of phase and inclined to the primary field. The resultant of the two fields will be elliptically polarized. The measurements of inclination of the polarization ellipse is named "Real component" and the "eccentricity" of the ellipse is the "Quadrature" or "Imaginary component" [7, 1].

4. Fieldwork, Data Presentation, Reduction and Interpretation

At First, if any local heterogeneous conductive body like a dyke within a conducting country rock encountered in the presence of a primary field, the In-phase component rises to a maximum, when this field approaches the conductor and then falls to a minimum changing its sign directly over the dyke, (Figure 2b) [1].

A noticeable and remarkable influence on the measured In-Phase and Out of Phase data is produced by many factors as, topographic relief, direction of conductor strike, the depth to the target, the width of the body, the dip of the body and its direction, the frequency of the field and the position of the target according to the transmitting station [1].

Usually in VLF.EM anomaly interpretation the cross-over point is searched for. But, in most cases regional EM components of considerable strength are superimposed and the cross-over in the normal sense may not be obtained. Thus the inflection point on the In-phase profile is normally considered to indicate the position of the conductor [5].

The most commonly used simple filtering technique was described by Fraser in 1969, in which the cross-over and inflection points are transferred into peaks (high positive). These transferred or filtered values could be used to draw a contour map which is useful in the qualitative analysis. Fraser’s method also reduces station to station background noise, amplifies near surface anomalies and attenuates deep source anomalies [11].

When a vertical conductor is present near the surface, a symmetrical In-phase profile would provide equal gradient on either side of the body, while if the conductor is inclined the gradients will become less similar. This asymmetry in the shape of the In-phase profile can thus be used to obtain an estimate of the dip of the conductor. Another useful diagnostic feature of the In-phase component can be used if the interpretation is made by measuring the horizontal distances between the positive peak and the negative trough in the In-phase profile for estimating the depth to the top of the target [10, 8 , 4].

However, the intensive field work has been carried out at the site. Firstly the direction of the concealed structure represented by the Cleveland dyke was traced as N60°W from surface features and a reference station was located with respect to the dyke position. The topography of the area taken is essentially flat and this avoids an unnecessary complication. Eight parallel traverses (as grid) in the direction N30°E (i.e normal to the concealed structure) with 200m maximum length and 50 m separation was set out by using a theodolite instrument with further traverse line was set out at the west of these mentioned traverses as given in (Figure 3). Two further traverses of 200m length at angles of 60° and 30° from the normal traverse line were also set out, see Fig above. Measurements were made with a station interval of 10m. The Em-16 equipment was used in the electromagnetic survey and the Canadian (NAA) electromagnetic station of (20khz) frequency range was selected as a transmitter for VLF measurements. The Em16 equipment was kept facing in a north easterly direction, which is in the same direction of the flux magnetic field.

The results of VLF.EM are presented as profiles of real and imaginary component values against the distance (Figures 4-14) whilst the filtered values obtained using Fraser's method is presented as contour map, (Figure 15).

Well to avoid some influences mentioned above, the area was chosen as flat, the direction of the traverses were taken perpendicular to the dyke structure even the transmitting station was Canadian (NAA) in which its primary magnetic field was almost parallel to the strike of the dyke body. Thus other factors dealing with the body itself were still variable.

By inspection all (Figures 4-12), almost an ideal VLF.EM anomaly pattern with moderate magnitudes were demonstrated. The most noticeable and interesting features can be seen by observing these anomalies, are that change in the behavior of the real component starting from (9-11) and the change in the position of the cross-over from the true axis of the VLF profiles, following the behavior change; such deviation might be due to the physical behavior of the dyke itself even the overburden conductivity and/or the conductivity contrast between the concealed structure (dyke) and the surrounding rocks. Well, if the thickness of the overburden layer is less than the width of the target (buried body), so the cross-over point will be found at zero position but when the overburden layer thickness is greater than the width of the target (buried body), the position of the cross-over point will be either in positive or in negative side and such behavior depends mainly on the value of the conductivity contrast. In this circumstances if the contrast is nearly high, then the cross-over point will be at positive side and vice versa. It should be noted that, this solution was found to be appropriate when a confirmation and supporting was obtained by electrical resistivity (as Wenner array) results which carried out in the same area (Figure 16).

Other interesting feature comes from the oriented VLF.EM profiles as (60° & 30°) in respect with the strike of the dyke. In this case, we will try to deduce the effect of the strike orientation on the VLF anomaly. An obvious stretching in the anomaly of (30°) and some slight stretched for (60°) was also shown. Thus, a shift in the positions of the maximum and minimum real component anomaly and cross-over were occurred. When such effect presents, it will make misleading to the position of the body even a mistake in other inspecting parameters. Returning now to the general pattern, (Figures 4-12) as we said before, one can calculate the parameter of the dyke from the characteristic feature of the anomaly such as, depth to top surface, dip and its direction in addition to the location or the position of the body. Since all these traverses were taken as perpendicular to the strike of the body, they revealed almost a symmetrical shape which indicates an approximate vertical dyke structure. By using [8] charts, the depth, dip and its direction were calculated quantitatively and tabulated in (Table 1) in addition to the location of the body along all traverses even the resistivty contrast ratio were taken from the electrical resistivity survey.

Table 1: Quantitative interpretation of the dyke parameters

Profile No.	Depth (m)	Dip (degree)	Dip direction	Body Location	Resistivity contrast ratio
1West	5	78	south	78	9
1East	5	80	south	85	9
2 East	3.5	80	=	85	9
3 East	3.5	78	=	85	6.5
4 East	5	78	=	85	5
5 East	3.5	80	=	85	2.5
6 East	5	80	=	85	2.6
7 East	5	80	=	85	2.6
8 East	5	80	=	85	5
9(60°)	6.5	75	=	80	4.7
10(30°)	17	65	south	70	4.7

With the exception of oriented profile result, the above table shows that the depth, dip with its direction and location belongs the target is ranged between (3.5-5m), (78-80) to the south and (85m) respectively. According to the parameters given from the interpretation of both oriented profiles, one can observe the effect of the strike orientation on the field anomaly value result as, depth, dip and location. On the other hand and by using Fraser filtering technique, the real component anomaly results of the VLF were filtered and contoured, which then displayed as a filtered map, (Figure 15), at intervals of (3%). The main anomaly is found to be characterized by a single symmetrical and strong positive one with maximum value of (31%), displayed clearly the presence of the concealed dyke structure and its location by observing its axis direction. The general trend of this distinct anomaly is in the direction of N60°W. The dip angle of the concealed structure seems to be indicated as vertical, since this anomaly reveals almost a symmetrical shape. Two more positive zones have been displayed in this map, with the first one in the north part of the map indicating the presence of very weak conductive zone, whilst the second zone was found in the south, split into two anomalies of different magnitudes. Both anomalies probably indicate the presence of two different conductive superficial materials. Finally, the general shape of the major dyke anomaly indicates that the anomaly continues on both west and east direction of the map which then reflects the presence of the dyke structure continues outside the investigated area, since the anomaly is characterized by open contour lines on both sides.

5. Conclusions

A field survey using VLF.EM method to locate and delineate the Cleveland dyke structure at Whitby Town north England was carried out. An ideal pattern VLF field anomaly was obtained with great similarity to those anomalies given numerically and experimentally, [10, 8 and 4], as an example in (Figure 17). Some interesting features dealing with the VLF field anomalies (Real component shape and cross-over location) were observed in which it reflected the condition of the concealed structure with regards to the surrounding conductivity contrast rock even the overburden thickness layer. Such condition was influenced the pattern of the obtained VLF anomalies which then an appropriate solution in correlation with electrical resistivity result was confirmed. A changeable location of cross-over up and down relative to the zero line was observed and suitable interpretation depending on the overburden thickness layer and conductivity contrast was given as well. The effect of profiles other than (90°) to the strike of the body has been detected in which attention should be taken when interpret an oriented anomalies. Quantitatively, the depth to the top surface, dip value, direction of dip even the location of the concealed dyke was calculated and be found having a range between (3.5 – 5m), (78°-80°) to the southern direction and at (85m) respectively, which is in a good agreement with the electrical resistivty results even with the available geological information. The continuity of the subsurface dyke structure in the east and the west direction was indicated, since the shape of the distinct anomaly was represented by open filtered contour lines. Finally, the VLF.EM technique has its performance in the field and reliable results with care can be obtained. However, an experimental model could be recommended to verify the Real and Imaginary component with their cross- over which then give more explanation about its location whether (it is above, below or at zero line).

References

[1]. Abdul-Razzak, M. I 1990 The development and application in electrical resistivity prospecting, Ph. D thesis, Mining and Mineral Engineering Department, Leeds University, England, U. K. Unpublished

[2]. Abdul-Razzak, M. I , Al-Douri, R. K and Baker, H. A 1984 Location of fault zones in Hit area by Electromagnetic Prospecting Method.(Scientific Report), Scientific Research Council, Building Research Center, Seismological Unit

[3]. Abdul-Razzak, M. I and Al-Hatimi, A 2000 The use of VLF.EM Method for Buried Body-Infinit Horizontal Cylinder-Location. Industerial Researches Journal, Vol: 10 No., Tripoli, Libya.

[4]. Abdul-Malik, M. M 1983 Problems of Interpretation of VLF Anomalies in the Search for Concealed Fluorspar/Galena/ Barites Ore Bodies, Ph. D Thesis, Mining and Mineral Eng. Dept. Leeds University, U. K, Unpublished.

[5]. Baker, H. A 1979 The Development of Analogue VLF.EM Models for Mineral Prospecting. Ph. D Thesis, Mining and Mineral Eng. Dept. Leeds University, U. K.

[6]. Baker, H. A and Abdul-Razzak, M. I 1985 The First Field Application of VLF.EM Method In Iraq. Journal of Iraqi geological Society, Vol. 19 No.1, Baghdad, Iraq.

[7]. Baker, H. A and Abdul-Razzak, M. I 1986 The Use of VLF.EM Method in Geological Mapping and Mineral Exploration. S.R.C /Scientific Report No. 103/86. Iraq

[8]. Baker, H. A and Myers, J. O 1979 VLF.EM Model Studies and some Simple Quantitative Application to Field Results. Geoexploration, Vol.17 PP: 55-63

[9]. Bayrak, N 2001 Exploration of Chrome Ore in Southwestern Turkey by VLF.EM. Journal of the Balkan Geophysical Society, Vol.5 No.2 pp:35-46.

[10]. Coney,D. P 1977 Model Studies of the VLF.EM Method of Geophysical Prospecting. Geoexploration, Vol.15 No.1

[11]. Fraser, D. C. 1969 Contouring of VLF.EM Data. Geophysics, Vol.34 pp:956-967.

[12]. Ngozi, O. P 2011 Integration of Geophysical Techniques for Ground Water Potential Investigation in Katsina-Ala, Benue State, Nigeria. A Thesis Submitted to the Depart. Of Geology, University of Nigeria.

[13]. Olsson, O 1980 VLF Anomalies from a Perfectly Conducting Half-Plane below an Overburden. Geoph. Prosp. Vol.28 PP:415-434.

[14]. Omossuyi, G. O and Oyemola, I. O 2012 An Assessment of Hydrogeologic Characteristics of Bamkeno's Hard Rock Terrain Using Geophysical Techniques.International Journal of Water Resources and Environmental Engineering, Vol.4 No.5 pp:120-133

[15]. Operating manual for EM16 VLF.EM, 1983 Geonics Limited.

[16]. Osinowo, O. O and Olayinka, A. I 2012 Very Low Frequency Electromagnetic (VLF.EM) and Electrical Resisitvity (ER) Investigation for Ground Water Potential Evaluation in a Complex Geological Terrain Around the Ijebu-Ode Transition Zones, Southwestern Nigeria. Gournal of Geophysics and Engineering , Vol.9 No.4

[17]. Phillip, W. J and Richards, W. E 1975 A study of Effectiveness of the VLF Method for the Location of Narrow Mineralized Fault Zones. Geoexploration, Vol.13 PP: 215-226

[18]. Poddar, M 1981 Very Low Frequency-Electromagnetic Response of a Perfectly Conducting Half-Plane in a Layered Half-Space. Geoph. Vol.46 PP: 1059-1067

[19]. Rayner, D. H and Hemingway, J. E 1974 The geology and Minearl resources of Yorkshire. Yorkshire geological society, England, U. K

[20]. Sampaio, E. E. S and Dias C. A 2001 Electromagnetic Profiling Interpretation across Vertical Faults and Dikes. Geophysical Prospecting Journal, Vol.49 No.1 pp:107-119.

[21]. Santose, A. M, Matues, A, Fieueiras, J and Goncalyes, M. A 2012 Mapping Ground Water Contamination around a Landfill Facility Using the VLF.EM Method – A Case Study-Geophysical Prospecting, Vol.60 No.2 pp:115-125 (Articles).

[22]. Saydam, A. S 1982 VLF.EM Interpretation Using Tilt Angle. Geoph. Vol.47 PP. 1594-1605

[23]. Sharma, S. P, Arkoprovo. B and Baranwal, V. C 2014 Recent Trends in Modelling of Environmental Contaminate, (Very low Frequency Electromagnetic Method: A Shallow Subsurface Investigation Technique for Geophysical Applications).

[24]. Usman, A. O, Omada, J. I and Omali, A. O 2014 VLF.EM Data Over Ishiagu, Nigeria. IOSR Journal of Applied Geology and Geophysics, Vol.2 No.4 pp:38-46.

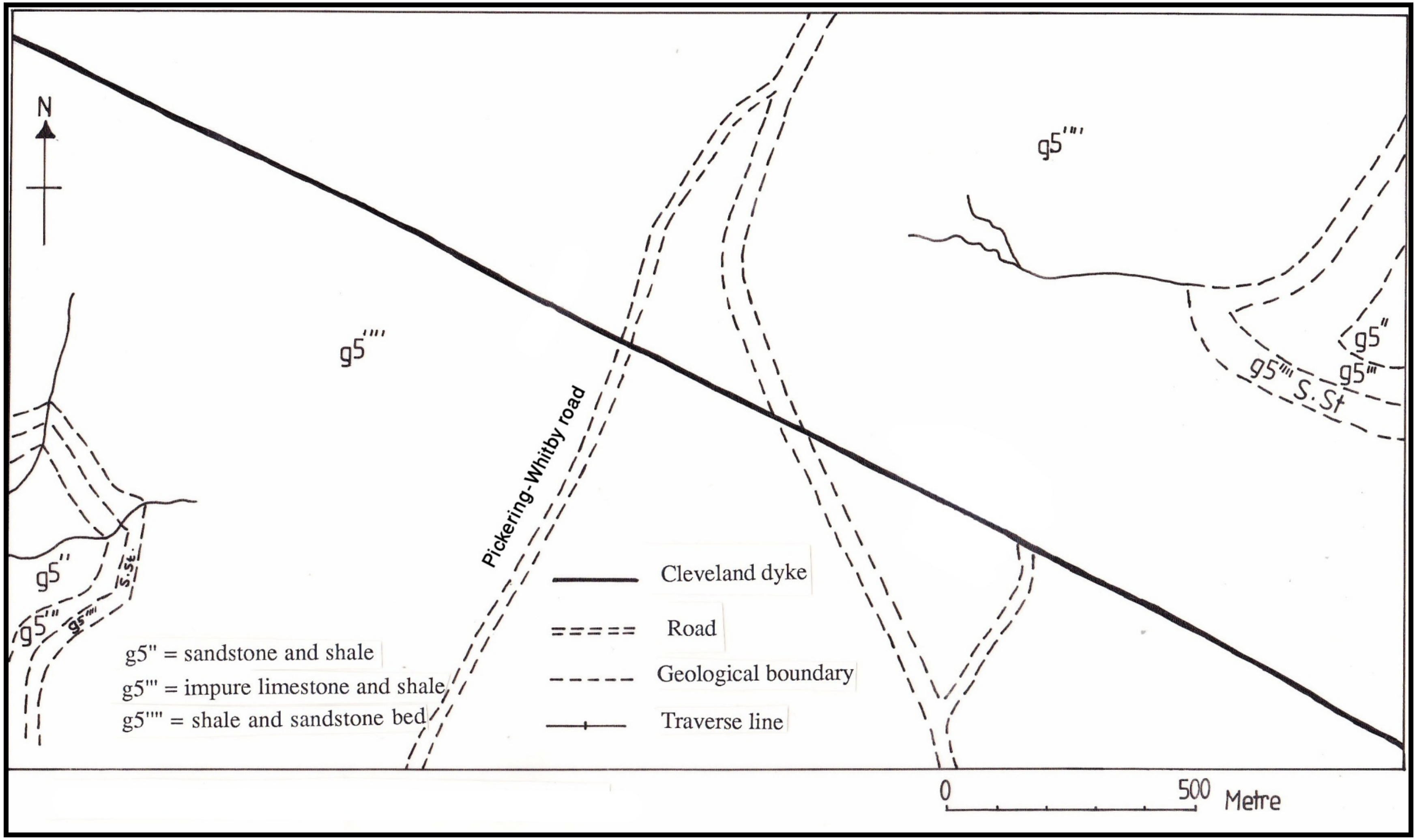

Figure 1: showing the location and local geology of the studied area and its surrounding Al whitby site (Rayner & Hamingway, 1974)

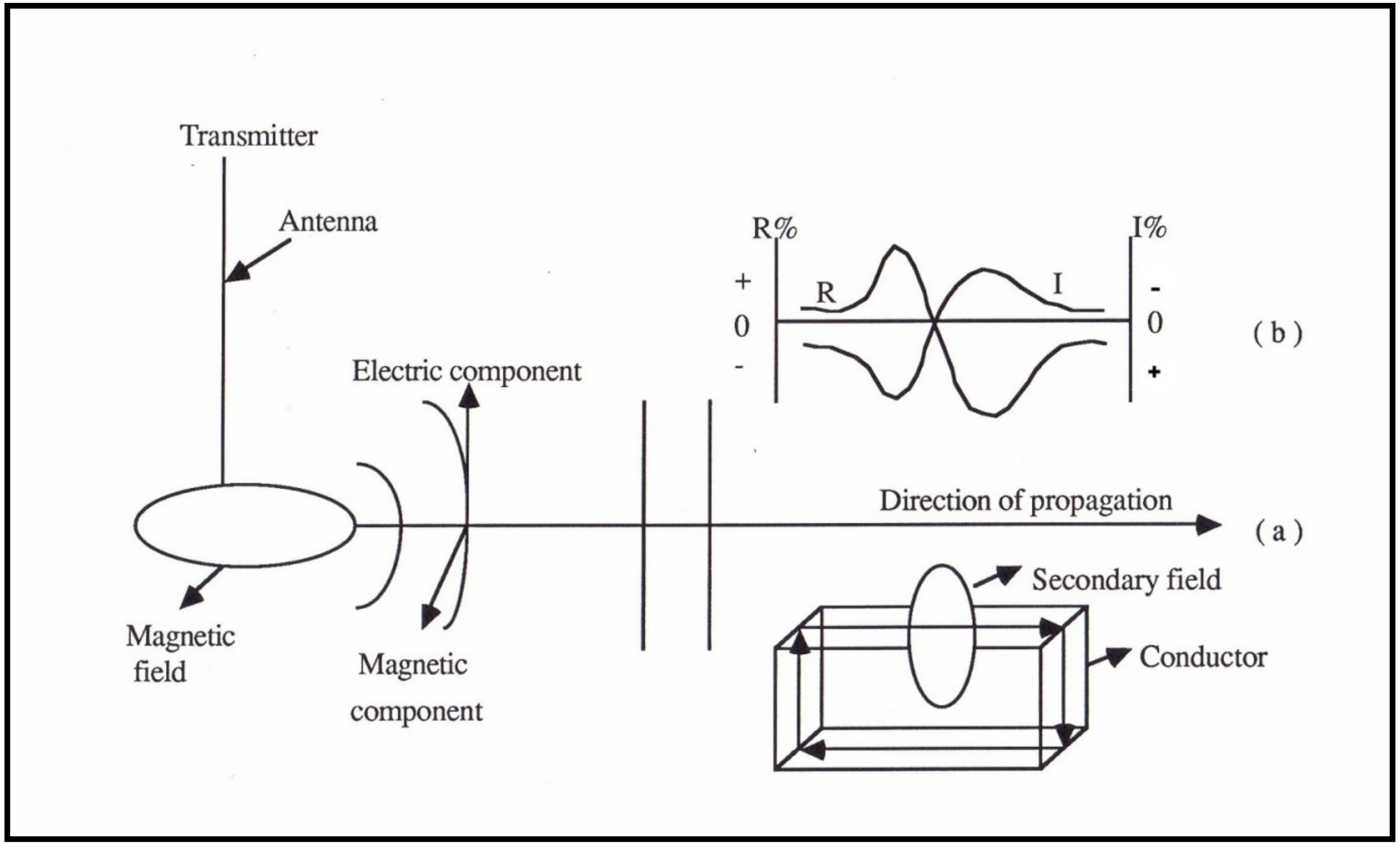

Figure 2a: Component and wave propagation associated with the VLF transmitter

Figure 2b: typical anomaly curve over a conductor, (Abdul-Razzak 1990)

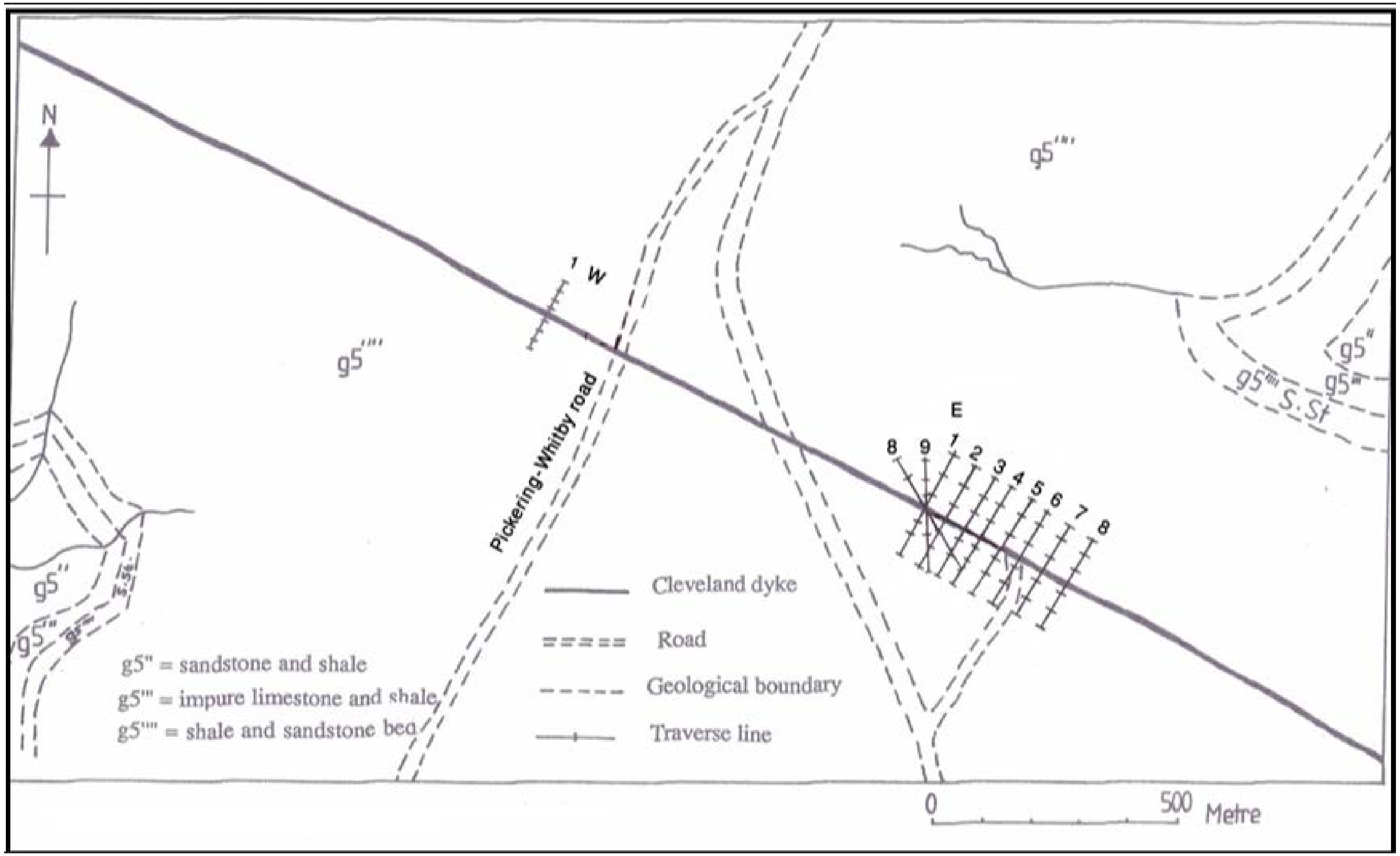

Figure 3: map showing the VLF. EM field traverses

Local gelogy and traverses layout, whitby site

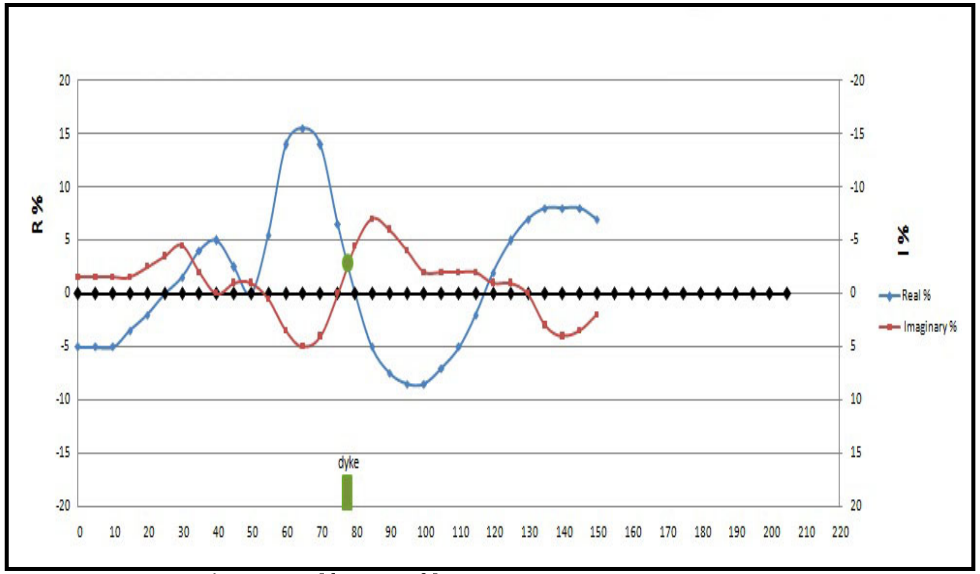

Figure 4: vlf.em profile. Traverse no.1, west, ton=90

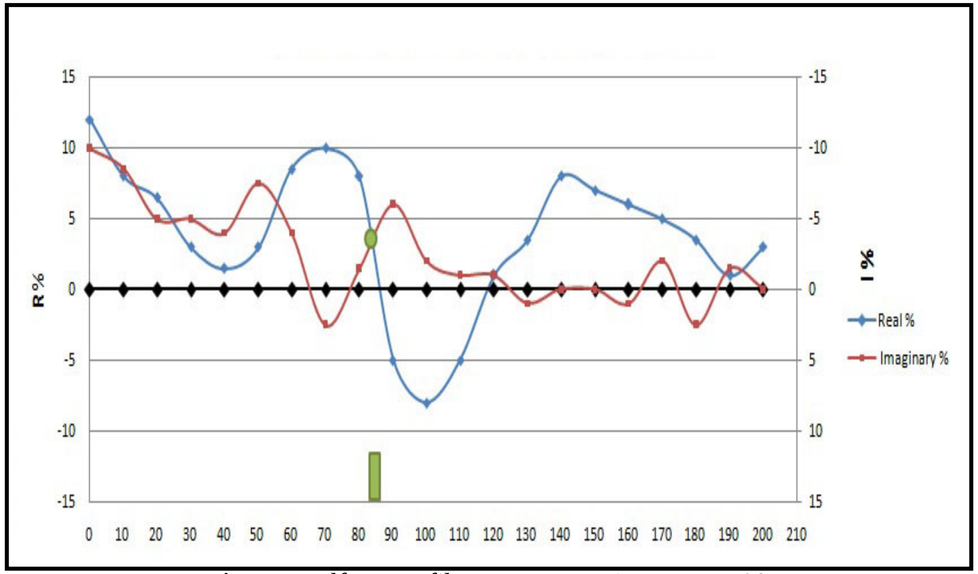

Figure 5: vlf.em profile. Traverse no.1, east, ton=90

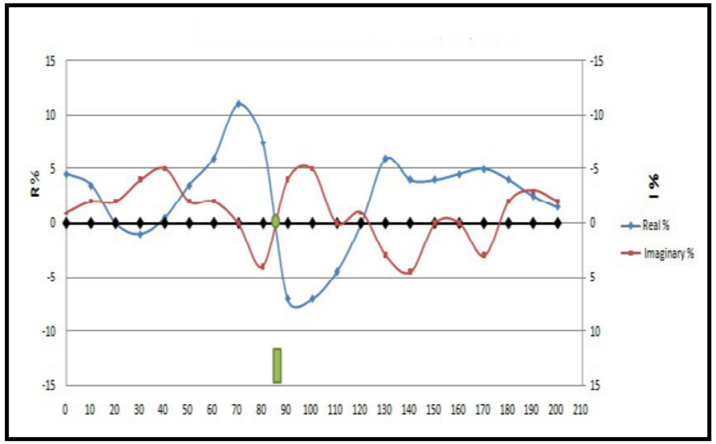

Figure 6: vlf.em profile. Traverse no.2, east, ton=90

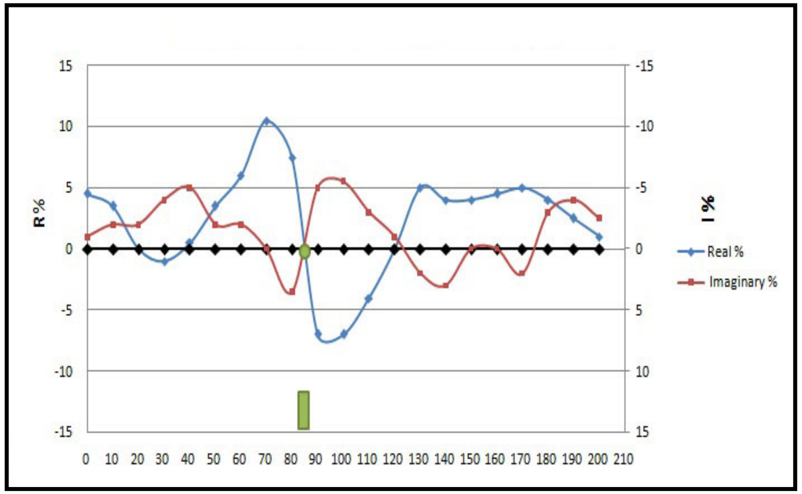

Figure 7: vlf. Em profile. Traverse no.3, east, ton=90

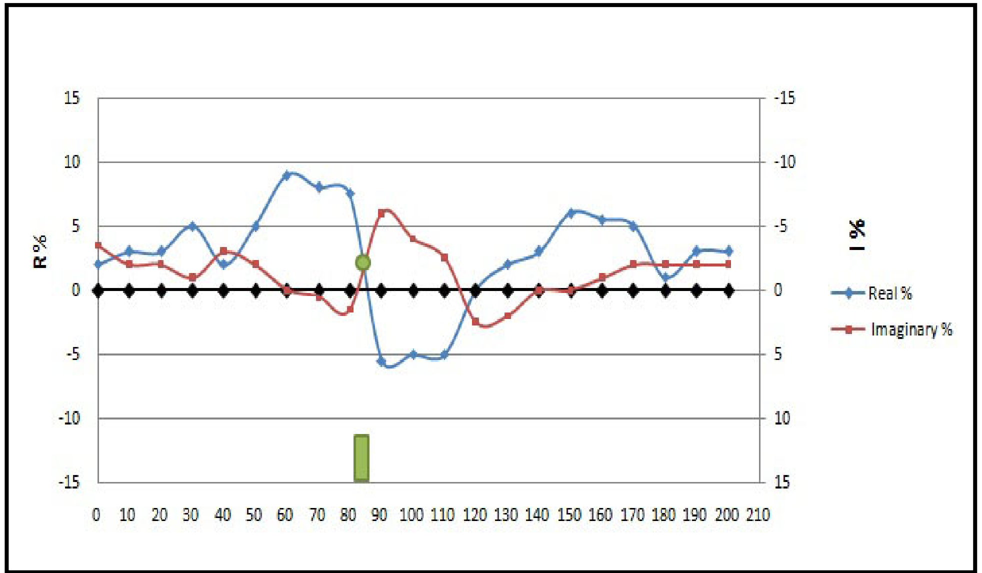

Figure 8: vlf.em profile. Traverse no.4, west, ton=90

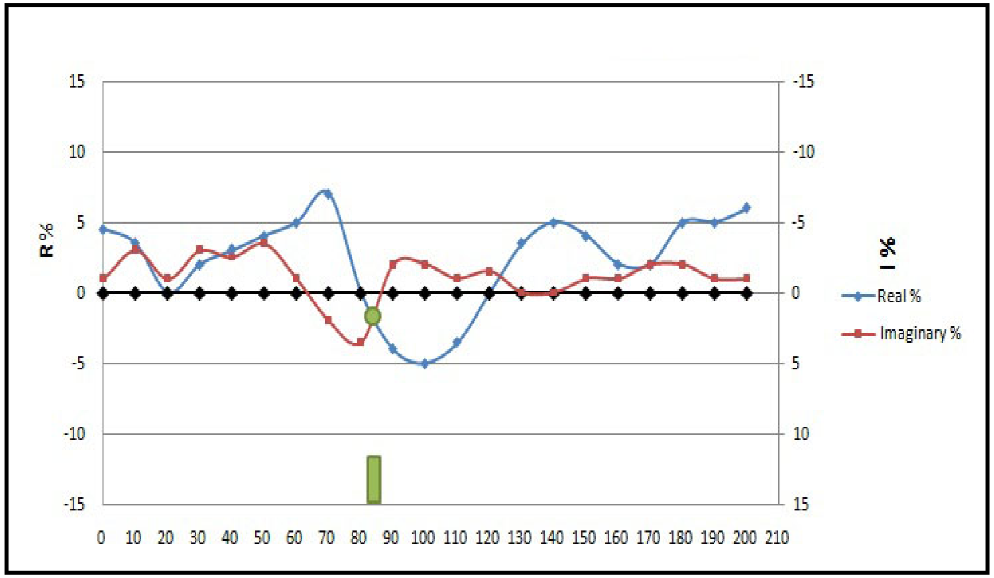

Figure 9: vlf.em profile. Traverse no.5, east, ton=90

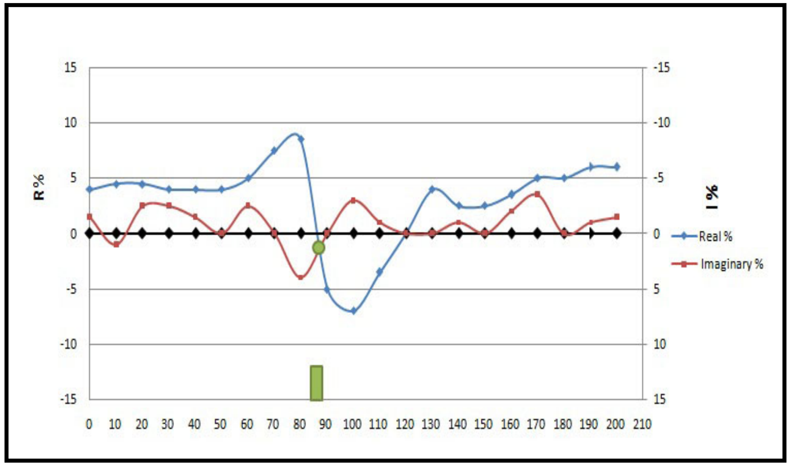

Figure 10: vlf.em profile. Traverse no.6, east, ton=90

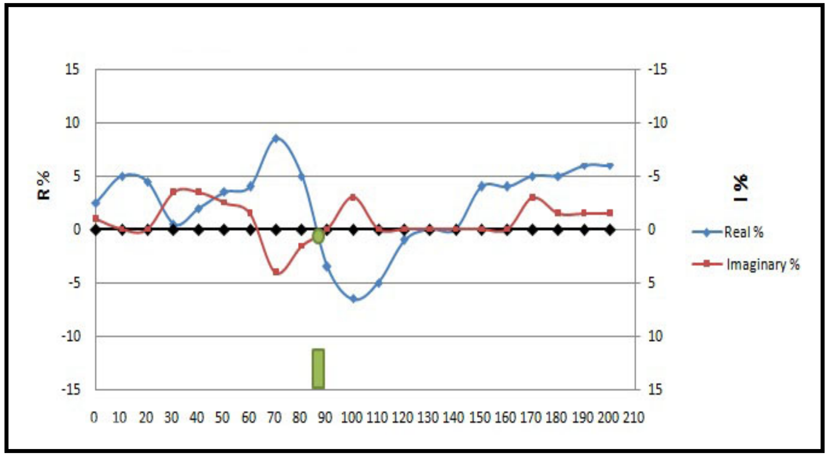

Figure 11: vlf. Em profile. Traverse no.7, east, ton=90

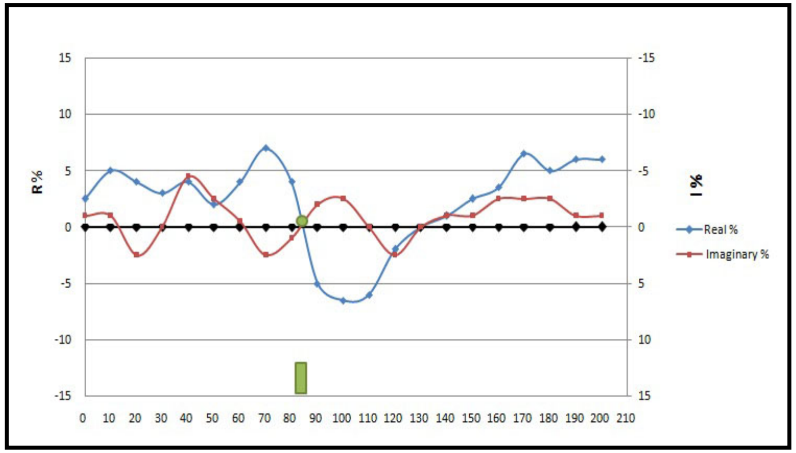

Figure 12: vlf.em profile. Traverse no.8, west, ton=90

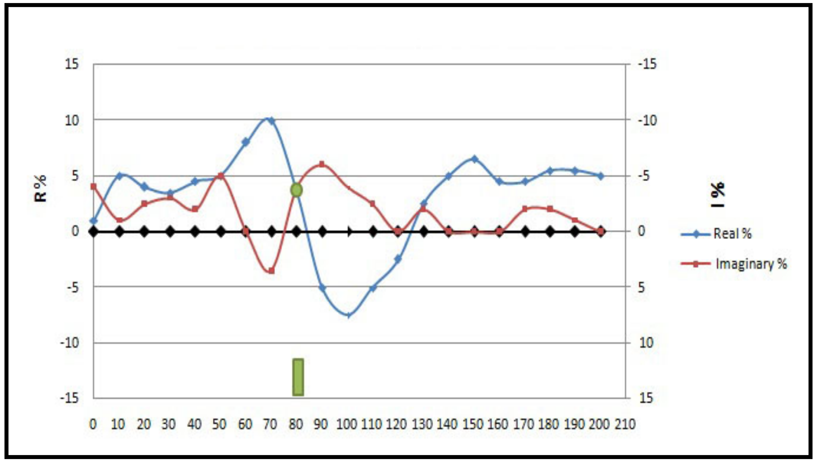

Figure 13: vlf.em profile. Traverse no.9, east, ton=60

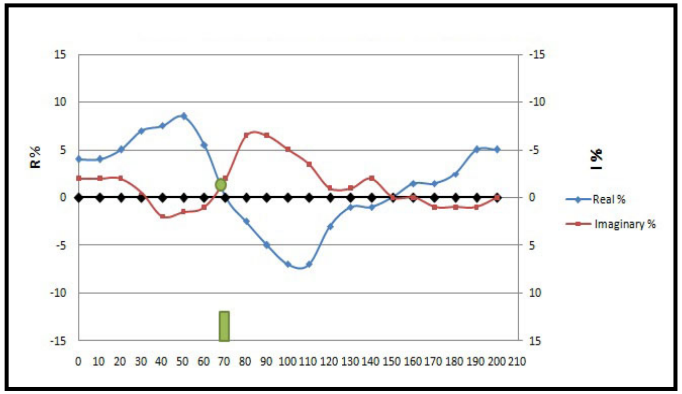

Figure 14: vlf.em profile. Traverse no.10, east, ton=30

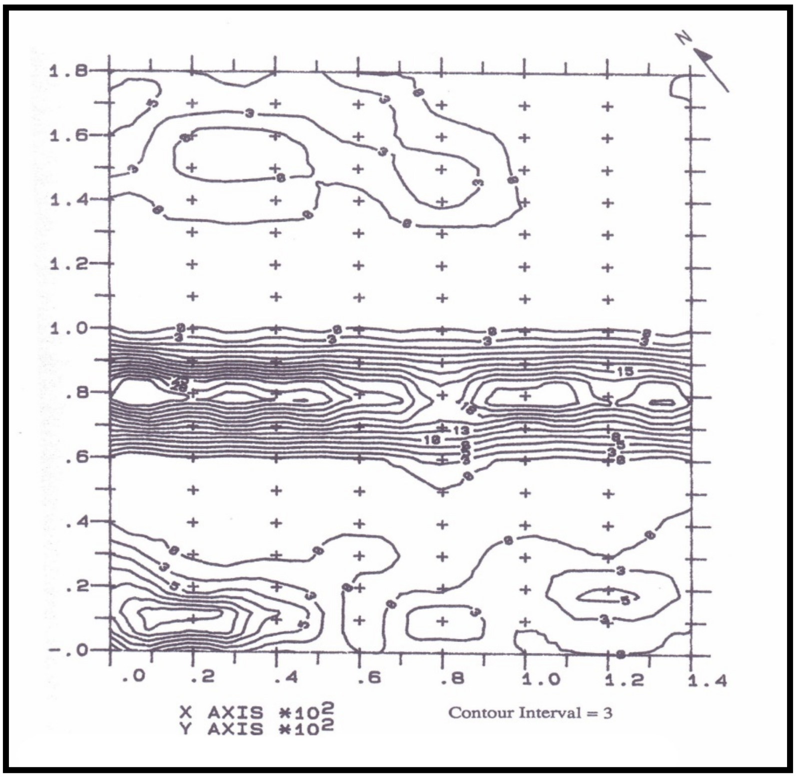

Figure 15: filtered VLF.EM contour map of the studied area

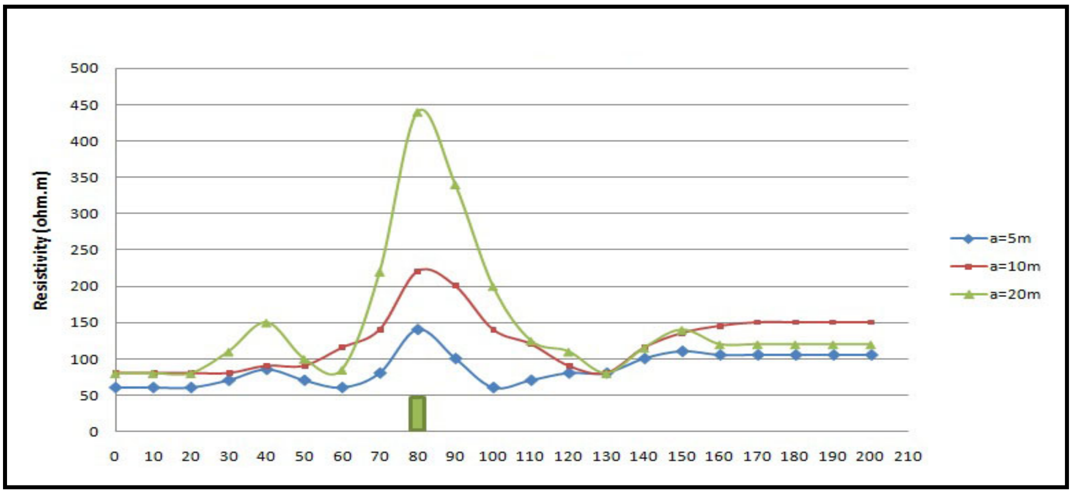

Figure 16: Wenner Electrode Array along Traverses East Ton = 90

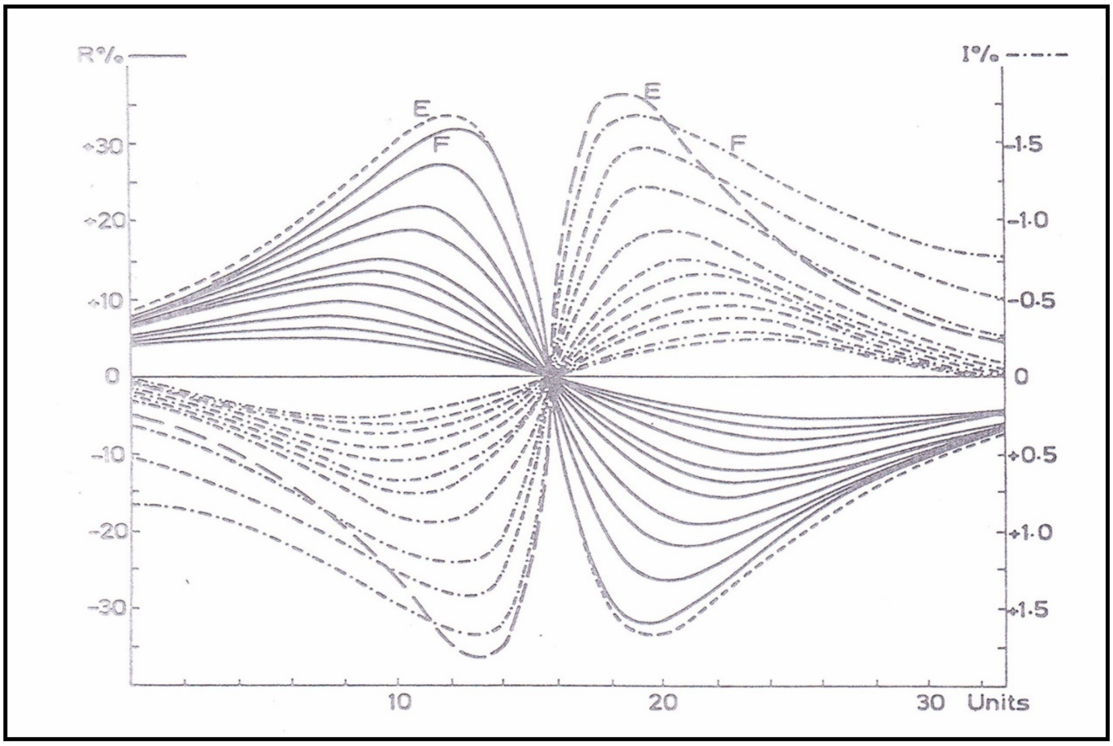

Figure 17: VLF. EM Model Profiles for a Vertical Conducting Brass Sheet with Depth of Cover Ranging from 0 to 10 Units, (Baker & Myers 1979)