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Geophysical Evaluation of Gold potential in Southwestern part of Kafin –Koro, Northwestern Nigeria

*[1]Abdullahi, S. *[2] Alabi, A. A.,*
[/1]Department of Geology, School of Mining and Geology, University of Rwanda Kigali
[2-4]Department of Geology, Federal University of Technology Minna, Nigeria
**Correspondence Author: Abdullahi, S.*

Abstract: *Kaffin-koro lies within the Kushaka schist Formation of the north-western block of Nigeria basement complex and Nigeria metallogeny province. The formation has been intruded by large volumes of granitic rocks that led to extensive migmatization of metasedimentary and metavolcanic rocks carrying substantial gold values, and it is suggested that the migmatization and metamorphic deformation of the metasedimentary and metavolcanic rocks gave rise to dispersion of gold in quartz veins and alluvial lateritic cover. Ground geophysical survey involving Magnetic, IP and Resistivity surveys was carried out in the study area. Profile interpretation of the residual intensity magnetic data of the area shows a complete wavelength of magnetic anomaly. Total magnetic intensity map exhibits zonation and alteration. This indicates hydrothermal alteration which is usually associated with mineralization probably as a result of intrusion. Residual magnetic field intensity map of generally show majorly NNW/SSE and N/S trending anomalies. Five major anomalous bodies with diagnostic chargeability and resistivity response were identified from nine IP profiles within the study area (two in the western part, two in the central part and one in the eastern end). The identified chargeable bodies' width ranges from 20m to maximally 60m.*

***Key words**: Geophysical evaluation, Kafin –Koro, Gold potential, Basement complex*

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I. Introduction

Gold mineralization in Nigeria is largely defined by different orogenic events and tectonic structures that accompanied it. Generally, gold mineralization in Nigeria is traversed by regional northwest - southeast lineaments or shear zone which have been considered as continental extension of oceanic transform fault - fracture zone, and it is suggested that the migmatization and metamorphic deformation of the metasedimentary and metavolcanic rocks gave rise to dispersion of gold in quartz veins within the Nigeria basement complex (Chuku, 1981). Geophysical technique in mineral exploration depends on the lithological, mineralogical and alteration characteristics of any deposit type. Gold deposit in shear and fault-zone (Au-quartz vein) deposits, aeromagnetic data can provide valuable mapping information by delineating lithologies, regional faults and shear zones which could be zone of gold potential.

Electromagnetic (EM) method has been successfully used to map faults, veins, contacts and alteration in the basement complex of Nigeria. Induced polarization (IP) method and gamma ray spectrometry have local applications in mapping massive quartz veins (resistivity highs) and associated alteration (potassium highs) zones. For epithermal styles of mineralization, several geophysical techniques has been used to delineate favourable structures and alteration mineral occurrence zone, these include regional gravity lows over thick volcanic sequences and local gravity highs associated with felsic intrusions, magnetic lows associated with alteration, regional potassium highs associated with felsic volcanism and local potassium highs with corresponding low Th/K associated with potassic alteration.

Geology of the study area

Kafin-koro area lies within the Kushaka Schist Formation of the north-western block of Nigeria basement complex and within the Nigeria metallogeny province, the formation has been intruded by large volumes of granitic rocks that led to extensive migmatization of metasedimentary and metavolcanic rocks carrying substantial gold mineralization (Garba, 2002). The geology of the area of investigation (Kafin-koro) is a typical geology of Kusheriki – Minna region, comprising of crystalline rocks that have been divided into three groups similar to that Nigeria basement complex, namely (Figure 1);

(i) The basement unit comprising gneisses and migmatite with relicts of supracrustal rocks.
(ii) The north-south trending schist belts composed of medium-to low grade supracrustal cover.

(iii) Intrusive granitic rocks (Older Granite Suite) which intrude both the gneiss, migmatite and the low grade schist belt.

Three schist belts have been mapped in Kusheriki – Minna region by Ajibade 1980. These belts include Kushaka, Birnin Gwari and Ushama schist belts, and are of typical of the geology of northwest schist belt of Nigeria.

Gold mineralization associated with quartz vein has been sub divided in to simple gold bearing quartz veins cutting schists, gneisses, granites and other rock types; gold bearing quartz veins with galena and occasionally other metallic sulphides; and quartz veins in dykes (Micheal Woakes, 1981). The gold mineralization in Nigeria is suggested to be as a result of low to mesothermal type of mineralization solutions which come in along foliation planes and fault zone associated with igneous activities (Chuku, 1981).

II. Methods and Materials

Magnetic survey measurements were taken with GSM-19v7.0 Over Hauser Instrument (Plates 1) manufactured by GEM SYSTEMS, Canada. The GSM-19v7.0 Over Hauser instrument is the total field magnetometer with inbuilt GPS - representing a unique blend of physics, data quality, operational efficiency, system design and options that clearly differentiate it from other quantum magnetometers. With data quality exceeding standard proton precession and comparable to optically pumped cesium units, GEM's sensors represent a proprietary innovation that combines advances in electronics design and quantum magnetometer chemistry. Electronically, the detection assembly includes dual pick-up coils connected in series opposition to suppress far-source electrical interference, such as atmospheric noise.

Base station method for correction of diurnal variations was used while the area selected for base station was magnetically quiet, i.e. free from moving automobiles and is not close or on top of any major outcrop. Fourteen (14) profiles of 2.4km long each trending east-west were covered in the area with GSM-19 v7.0 Over Hauser instrument. The stored data from the instrument is dumped on a computer system. The dumped data is later saved in an Excel Spread-sheet for easy management. All Magnetics Stations were tied to their respective coordinates. Quality Control (QC) and Quality Assurance (QA) were then applied on the raw data through visual inspection. This is useful in making sure that all survey specifications have been adhered to. Observed geology, cultural features and all possible source of noise aided the execution of Quality Control and Quality Assurance on the data.

Based on the result from the magnetic survey result, anomalous areas delineated were further explored using Induced polarization and resistivity imaging. Such areas were based on unique Magnetic response which area diagnostic of potential mineralization. Induced polarization (IP) technique involves measuring a transient decay after turning the transmitter off. There are many electrode arrays that are used in electrical imaging (*e.g.*, Wenner, Schlumberger, dipole-dipole etc.) depending on the application and the resolution desired. The dipole-dipole array was used for this survey. Induced polarization (IP) and resistivity imaging survey was carried out simultaneously with Geomative GD-10 Supreme 2D Geoelectrical system manufactured by ST Geomative Co., Ltd, China. GD-10 series. Powerful self-checking function for the high-quality data during measurement which including Grounding R test, switcher test and cable leader test. Ten (10) lines of about 360m to 600m each were covered with the Geomative GD-10 Supreme 2D Geo-electrical system in the study area (Figure 2).

The value for each IP and resistivity combination is plotted on a pseudo-section which resembles a cross section of the region under the profile. Pseudo-section plots apparent resistivity and chargeability at the point where lines drawn downward at the centre of each dipole intersect. This traditional pseudo-section exaggerates the depth of the anomalous materials; therefore 2D inversion of the apparent resistivity and chargeability data was carried out using finite element (Loke, 2011).

Plate no 1: Magnetic and Induced polarization and resistivity data acquisition

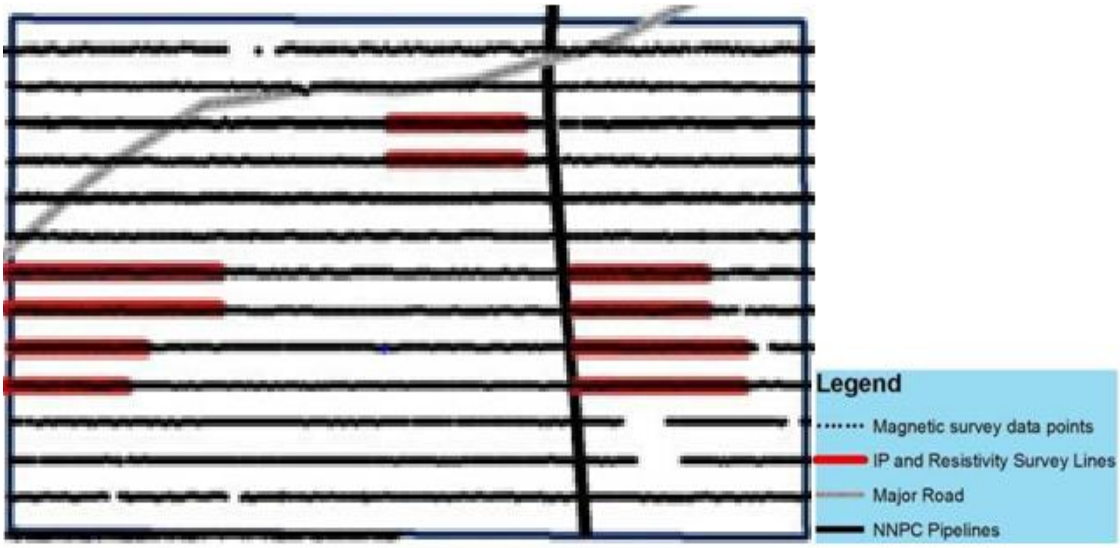


Figure no 2: Geophysical Data Acquisition Map

III. Data processing and interpretation

Magnetic Data Processing

First stage in magnetic data processing involve the removal of diurnal variations of the earth's magnetic field, which may be resolved into secular changes, solar-diurnal changes, lunar changes and changes resulting from magnetic storms (Dobrin and Savit, 1988). This represent very small but more rapid oscillations in earth's field which have a periodicity of about a day and amplitude averaging about 25 gammas and can cause a variation of the order of 50 gammas/hour. There are different ways of removing diurnal variations. In this study, base station method was used to correct for diurnal variation. Tuning field of 33,000nT was used for magnetometer throughout the survey. After recording, the magnetic data for a particular day were reduced to an arbitrary datum (i.e., base field for the day). The reduced magnetic data for all profiles was then put into a database for further two dimensional processing and interpretation.

Micro leveling or decorrugation method was used to remove line-to-line leveling errors of magnetic data which are visible as linear anomalies parallel to the lines. This was achieved using Butterworth and cosine directional filters. To estimate the geometry of geologic structures and depths to causative bodies, mathematical functions were applied to the total intensity magnetic field data. These were regional-residual calculations, derivatives calculations and source parameter imaging (SPI). Figures 3 show the colour-shaded map of the total magnetic intensity map of the study area.

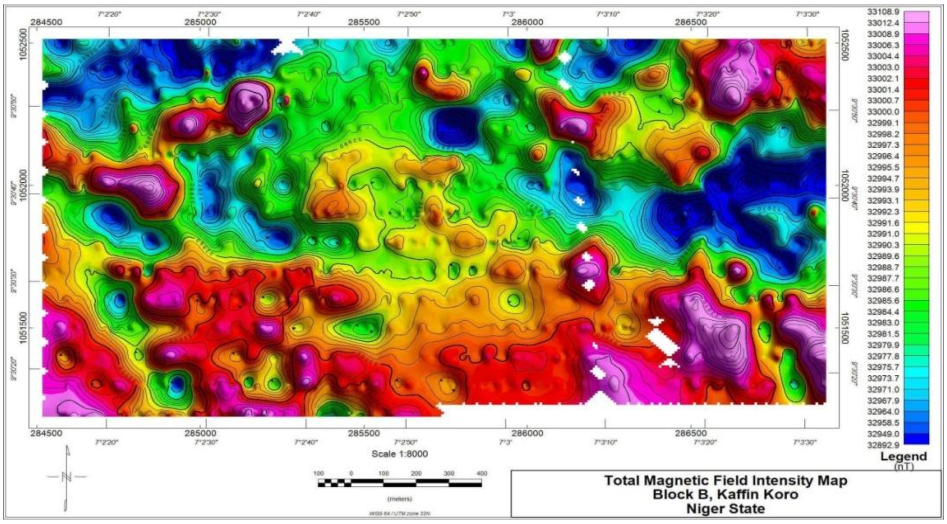


Figure no 3: Total Magnetic Field Intensity map of the study area

Observed magnetic field at every point is a vector sum of various components, such as the regional field and the local field components. In addition to induced magnetism, rocks may also have remnant magnetic component (Clark, 1997). Remnant magnetism is the effect of the primary magnetic field at the time of rock formation. The total magnetic response is proportional to both the induced magnetism as well as remnant magnetism (Luyendyk, 1997). The regional field was assumed to be a first order polynomial plane and it was derived by least-square fitting of a plane:

$$T(x,y) = (a_o + a_1x + a_2y) \text{ - - - - - - - - - - - - - - - - - } (1)$$

Where x and y are unit spacing along the two axes of the area and a_o, a_1 and a_2 are the coefficients of the plane. From this relation the regional gradients along any line were calculated. This was achieved with the aid of Geosoft MAGMAP software which is based on least square (best-fit polynomial). The computed regional anomaly (Figures 4) were subtracted from the corresponding total magnetic field intensity map (Figures 3) to obtain the field due to local geological events i.e. residual magnetic maps (Figures 5). The computed residual field components of the magnetic data were calculated along profiles and were plotted against station locations for profile analysis. These plots of residual fields were stacked to allow for qualitative interpretation (Figure 6).

Several derivatives of the residual total magnetic field provide value-added products that may contribute to the geological interpretation of magnetic data. Since analytic signal is useful in locating the edges of magnetic source bodies, particularly where remanence and/or low magnetic latitude complicates interpretation; the analytical signal map of the residual magnetic field were produced (Figures 7). In order to observe the near-surface magnetic anomaly and likely vein structures in the study area, first vertical derivative and horizontal gradient maps (Figures 8) were produced.

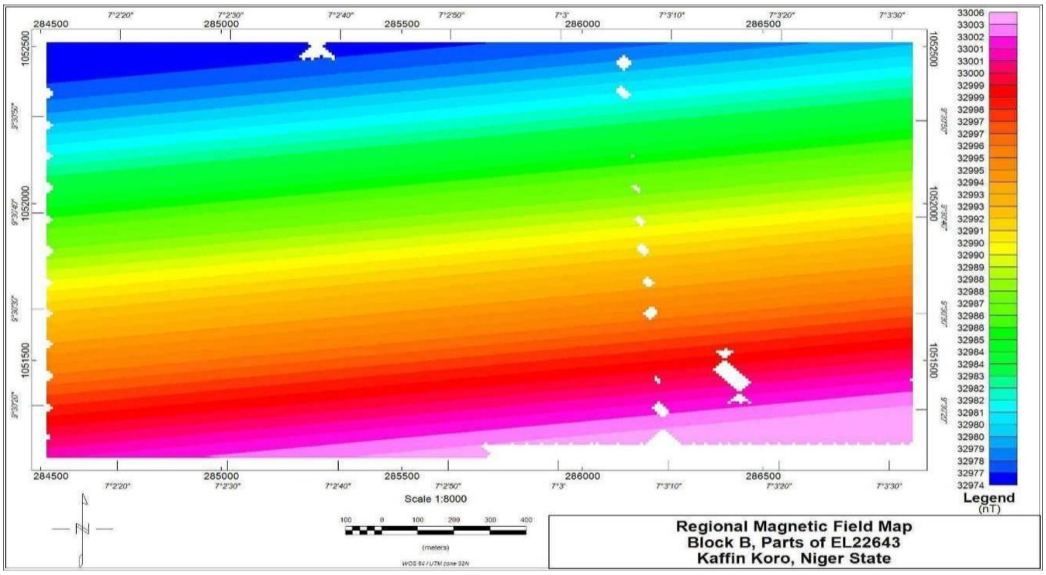


Figure no 4: Regional Magnetic Field Intensity map of the study area

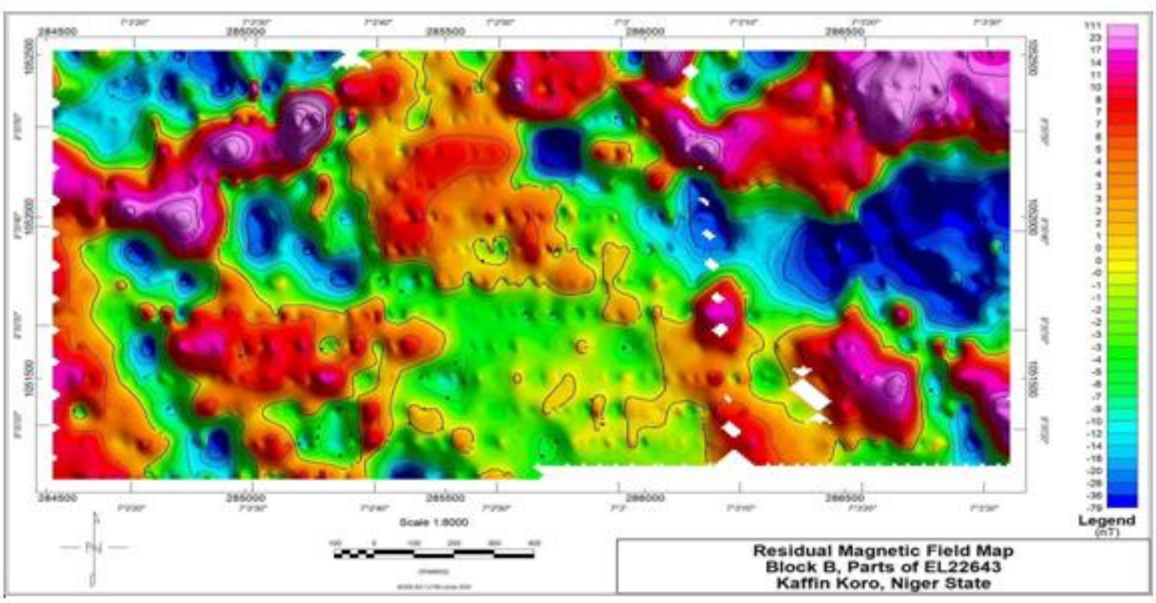
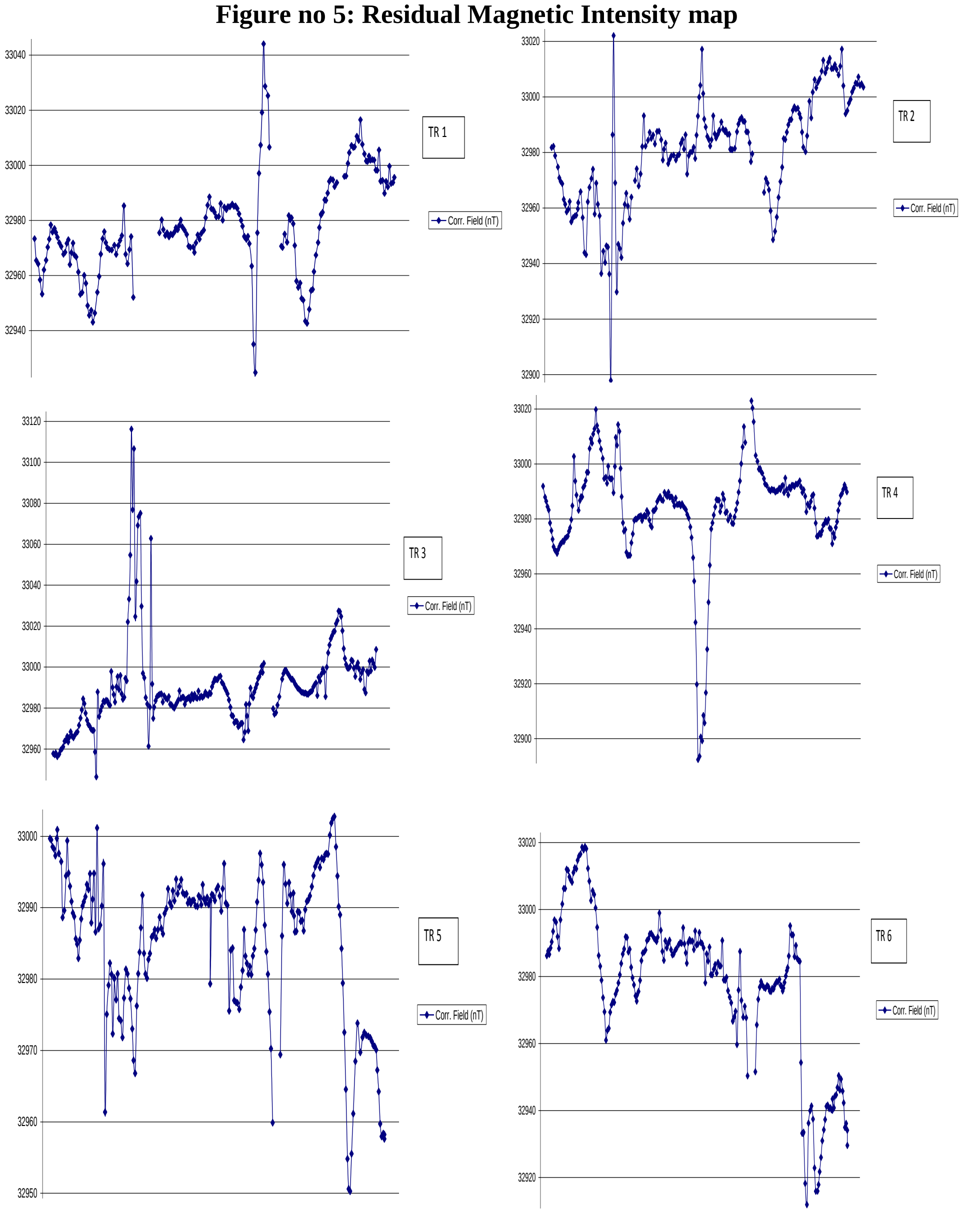


Figure no 5: Residual Magnetic Intensity map



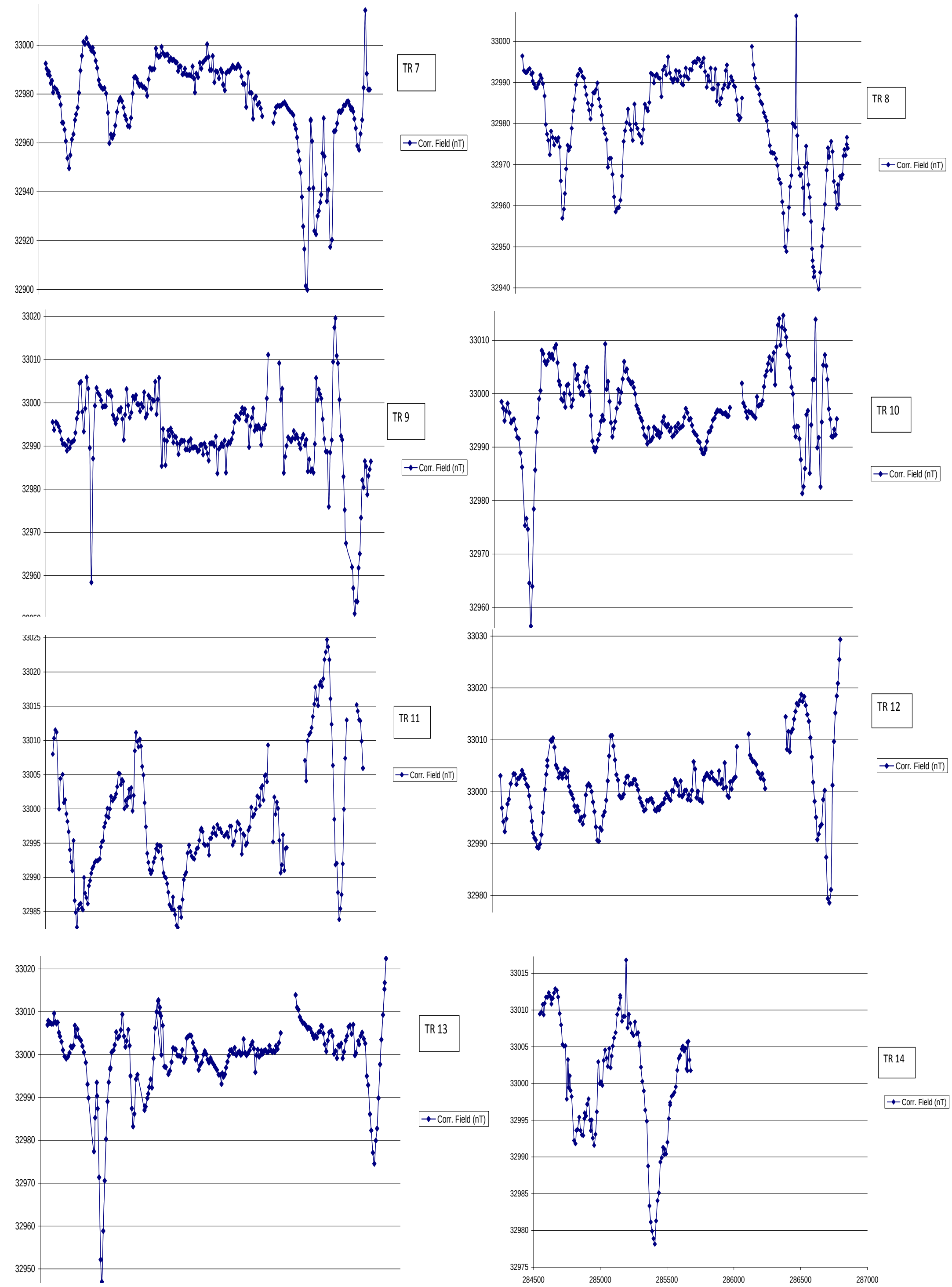


Figure no 6: Stacked plot of the magnetic data of the study area

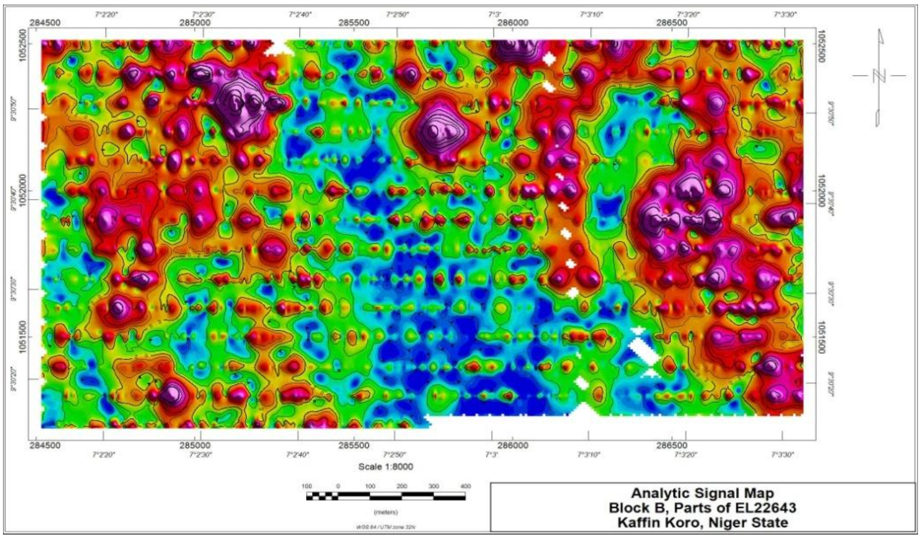


Figure no 7: Analytical signal grid of the TMI grid of the study area

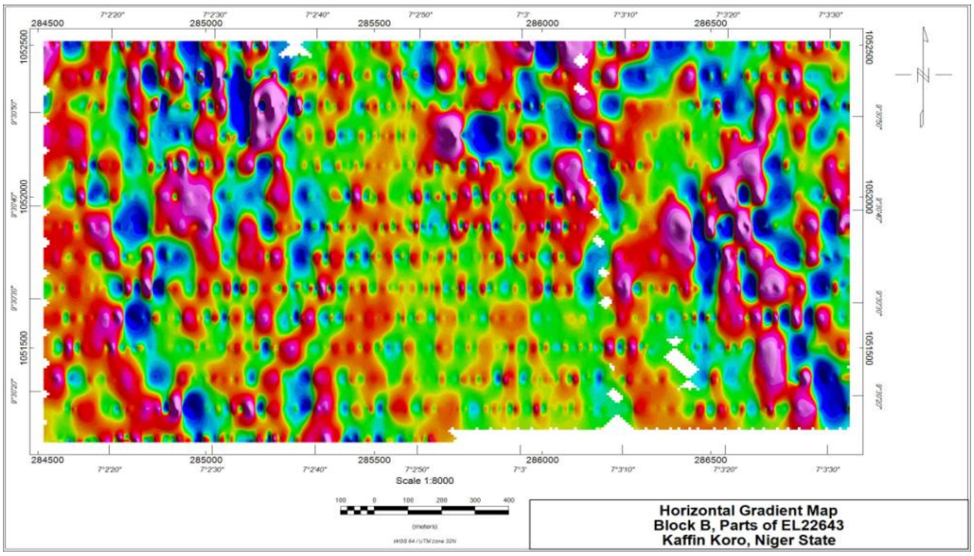


Figure no 8: Horizontal Gradient Map of the TMI grid of the study area

IV. Interpretation of magnetic survey data

The magnetic profiles in the study area showed anomalies of varying amplitudes (Figure 6). The variation in amplitudes of the residual intensity may be due to the presence of geological structures such as faults, dykes and contacts in the area. The total magnetic intensity map of the area (Figures 3) exhibits zonation and alteration. This indicates hydrothermal alteration which is usually associated with mineralization probably as a result of intrusion. The anomaly minima and maxima amplitude signature shows positive magnetic amplitude (maxima) ranging from -79nT to 111nT (Figure 6). This is quite appreciable for reasonable magnetic anomaly and it suggests that the magnetic susceptibility of the study area is contrasting, hence suitable for magnetic method of exploration. The residual magnetic field intensity map of generally show majorly NNW/SSE and N/S trending anomalies with few trending in NE/SW (Figures 5). This shape of magnetic signature obtained in the ground magnetic survey generally suggests a step or an edge structures like dyke or intrusion, such structures are of interest may hold mineralization at certain depth.

RES2DINV software was used for the 2D-inversion of the resistivity and IP data from the

Geomative GD-10 Supreme 2D Geo-electrical system. Observed apparent resistivity and IP data presented as pseudo-section and 2-D inverted resistivity-IP mode show a qualitative idea of resistivity and chargeability distribution in the subsurface (Figures 9 to 18). Primary gold occurrences in the northern Nigeria schist belts are associated with sulphide mineralization, hence high chargeability become a major factor for prospect and delineation. Quartz veins are characterized by high resistivity (low conductivity). Most primary gold mineralization in the schist belts commonly occurs in quartz veins within different lithologies, therefore geophysical characteristics of the quartz veins becomes another important factors in prospecting and delineation gold deposit. From the IP and resistivity models (Figures 9 to 18), several bodies with high resistivity with corresponding high chargeability were identified at a relatively shallow depth (less than 48m) in the study area. IP survey revealed that most of the magnetic anomalies investigated are chargeable and that their chargeability increases with depth. Also some massive chargeable bodies were delineated at depth (Figure 15). Five major anomalous bodies with diagnostic chargeability and resistivity response were identified from nine IP profiles within the study area (two in the western part, two in the central part and one in the eastern end) (Table 2). The identified chargeable bodies' width ranges from 20m to maximally 60m. Their approximate length and orientation could not be determined from the IP data since the bodies were delineated on a single profile except one (Figure 19).

V. Conclusion

Combining the results of the three geophysical methods reveal a wide range of linear structures suspect to be quartz veins which are believed to host ore mineralization were identified. Careful interpretation and technical assessment of the general results, it can be inferred that some of these structures are probably mineralized veins with varying degrees of characterization. Responses to physical parameters also revealed that some of the structures delineated from the magnetic data are conductive while others are non-conductive, while some are within a resistive host and others are within a conductive host. Several of such structures trending mostly NE-SW and N-S were identified. About 42 of the anomalous zones characterized by high chargeability and high resistivity were identified from Six IP profiles within the study area (Table 1). The identified chargeable bodies/structures length ranges from less than 50m to maximally 400m while the width ranges from 20m to maximally 80m based on the IP signatures.

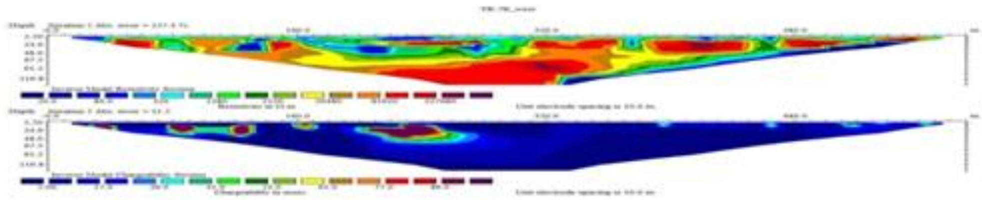


Figure no 9: 2-D inverted IP-Resistivity mode plot of Profile 7B_West (284550 to 285150, 1051900)

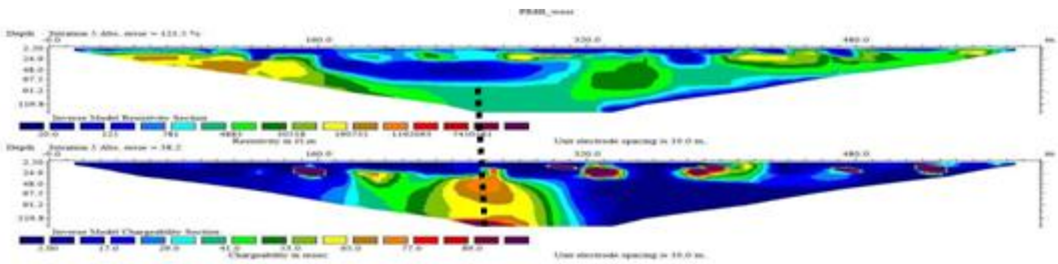


Figure no 10: 2-D inverted IP-Resistivity mode plot for Profile 8B_West (284550 to 285150, 1051800)

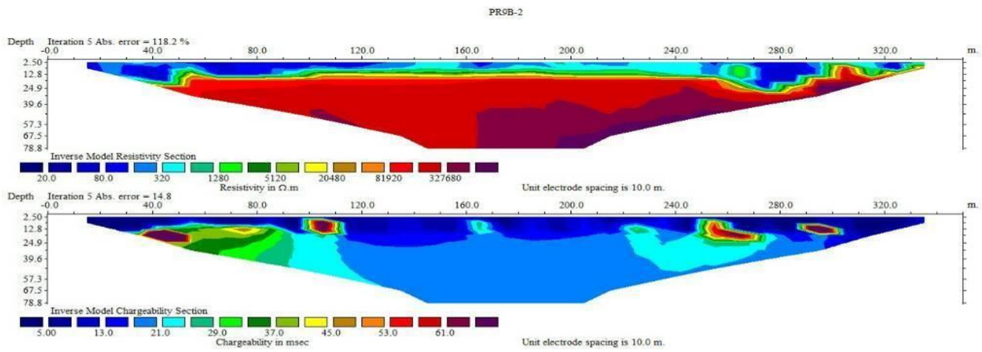


Figure no 11: 2-D inverted IP-Resistivity mode plot for Profile 9B_West (284575 to 284928, 1051700)

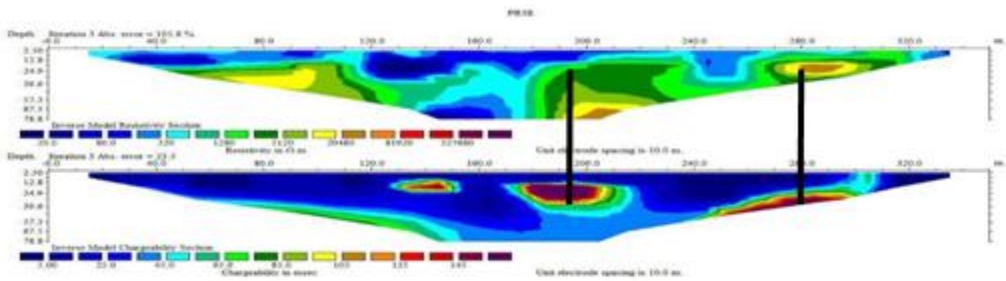


Figure no 12: 2-D inverted IP-Resistivity mode plot for Profile 10B_West (284520 to 284873, 1051600)

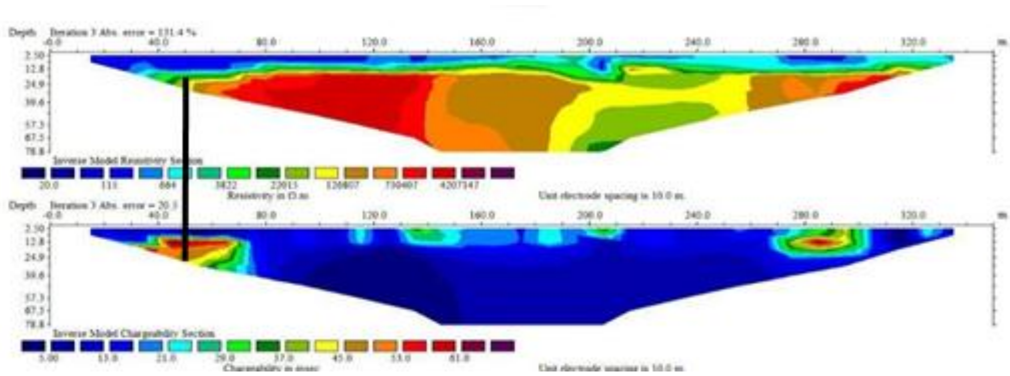


Figure no 13: 2-D inverted IP-Resistivity mode plot for Profile 3B_Central (285660 to 286024, 1052300)

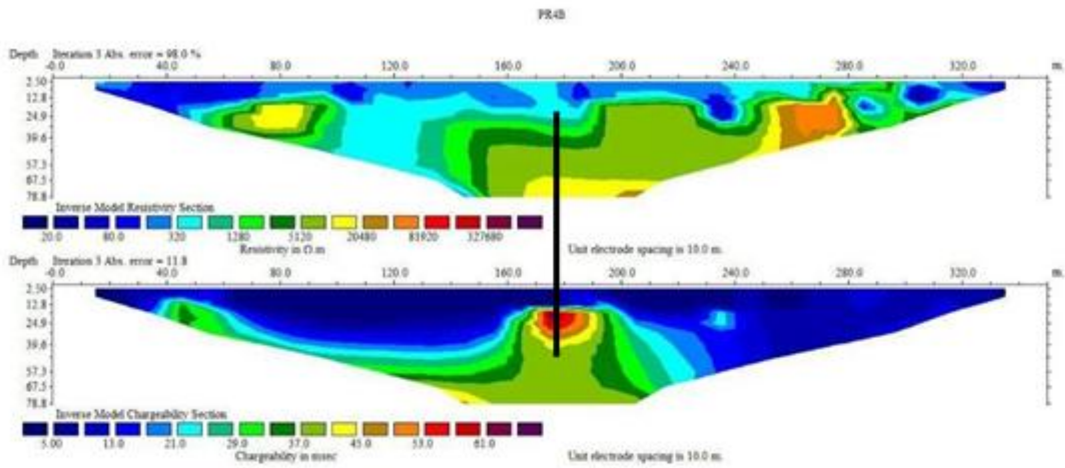


Figure no14: 2-D inverted IP-Resistivity mode plot for Profile 4B_Central (285670 to 286023, 1052200)

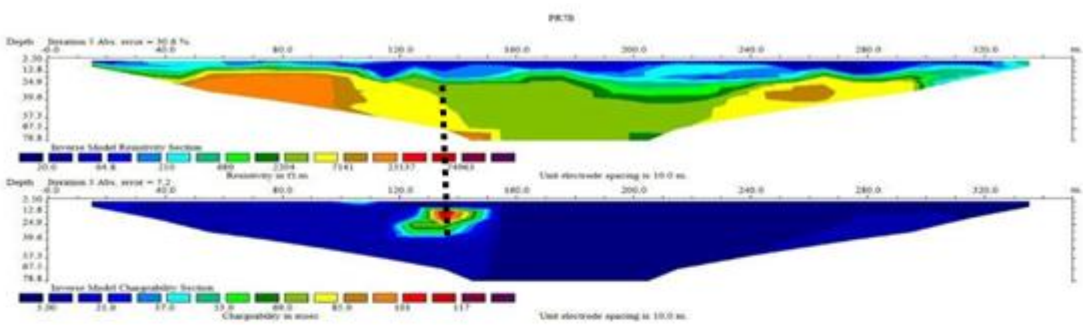


Figure no15: 2-D inverted IP-Resistivity mode plot for Profile 7B_East (286200 to 286559, 1051900)

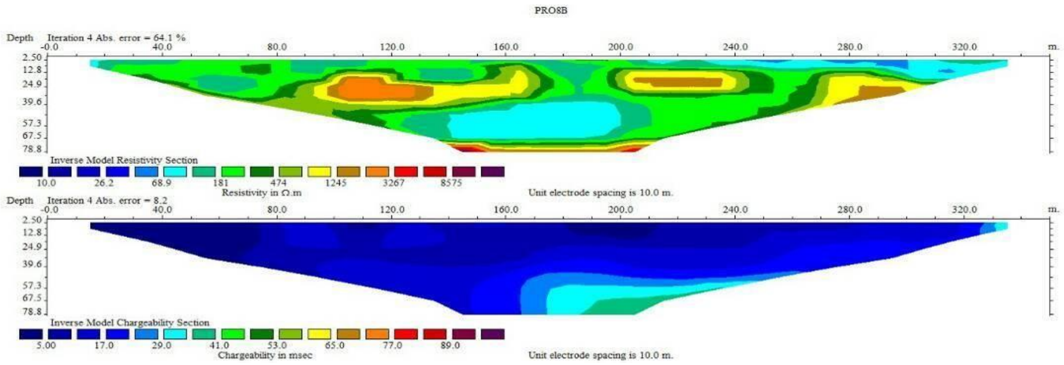


Figure no16: 2-D inverted IP-Resistivity mode plot for Profile 8B_East (286200 to 286550, 1051800)

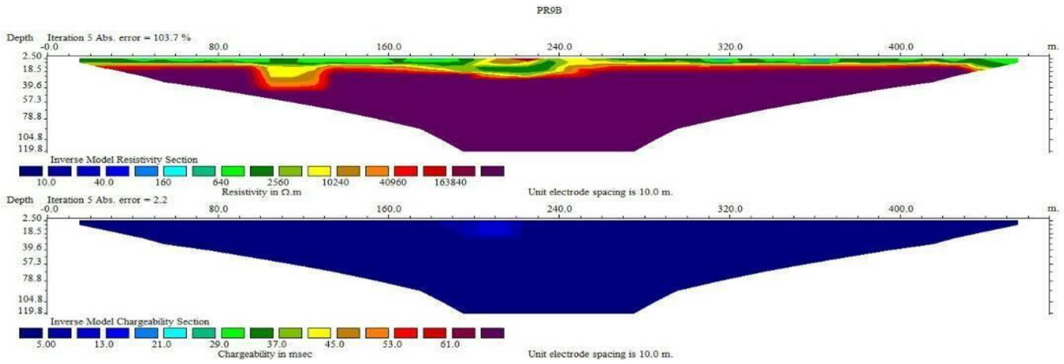


Figure no 17: 2-D inverted IP-Resistivity mode plot for Profile 9B_East (286200 to 286666, 1051700)

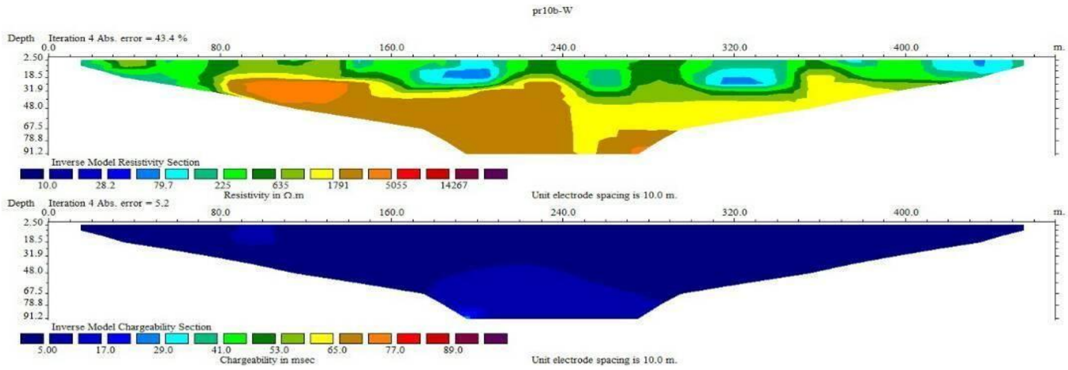


Figure no18: 2-D inverted IP-Resistivity mode plot for Profile 10B_East (286200 to 286669, 1051600)

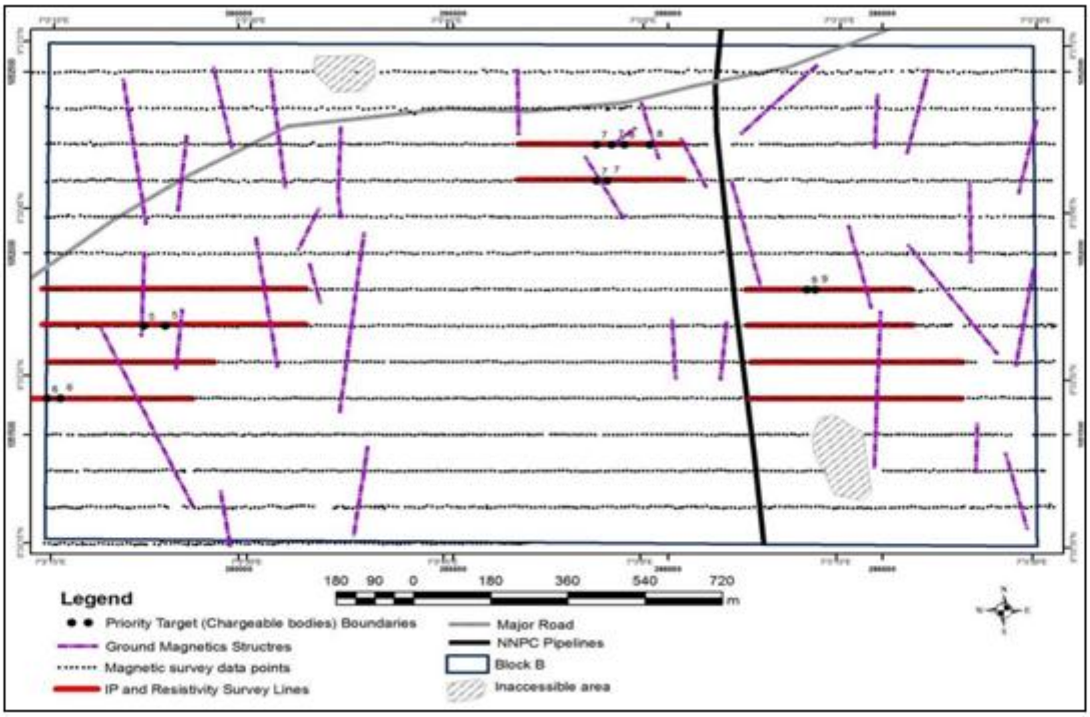


Figure no 19: Mineral target map for the study area

Table no1: Characteristics of the identified chargeable bodies/veins

TR8B_W	284780	284830	1051800	48m	Good	High	Very High	5
TR10B_W	284555	284585	1051600	15m	Good	High	Very High	6
TR3B_C	285835	285870	1052300	15m	Good	Very High	Very High	7
TR3B_C	285900	285960	1052300	25m	Good	Very High	Very High	8
TR4B_C	285835	285860	1052200	15m	Good	High	Very High	7
TR7B_E	286325	286345	1051900	15m	Good	Very High	Very High	9

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