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DELINEA TION OF LEAD-ZINC (Pb-Zn) MINERALIZATION OCCURRENCE USING INDUCED POLARIZATION METHOD AT KAMBARI AREA, KARIM-LAMIDO OF TARABA STATE, NORTHEASTERN NIGERIA.

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ABSTRACT: In order to evaluate the Lead – Zinc (Pb-Zn) mineralization potential, determine the depth of occurrence and provide preliminary recommendations for further exploration and exploitation activities, a geophysical investigation involving the induced polarization method was carried out at Kambari area, Karim-lamido of Taraba state Northeastern Nigeria.

Induced polarization measurements involving the dipole-dipole array were carried out along four traverses of approximate length of 1.2km each using the GDD IP transmitter and GDD IP receiver with multi-electrode system and spacing of 50m. The data set were processed using the commercially available Oasis Montaj, Surfer and Arc map software to produce pseudo-sections and maps respectively to provide the lateral and vertical variations of subsurface chargeability of the study area. The study area reveals areas of low chargeability (-77 to 4) mV/V, moderate chargeability (5 to 7) mV/V and high chargeability (8 to 66) mV/V and low resistivity (10 to 25) Ωm. moderate (26 to 33) Ωm and high resistivity values of (34 to 597) Ωm at a depth of approximately 200m – 300m. Several mineralized zones were delineated and identified from the study area, they continued from one survey line to the next and the mineralization were consistent with the general trend of the geological structural trends in Nigeria. Lead-zinc (Pb–Zn) mineralization in the study area display contrasting values in resistivity and chargeability, with regards to the sedimentary host rocks. The nature of the mineralization is non-fairly-well distributed from the pseudo-sections.

Induce polarization for this study proved a useful tool for mapping lead-zinc occurrences and its hereby recommended for mineral exploration surveys in other geologic areas for the mapping of disseminated mineralization.

Keywords: Lead-Zinc; mineralization; dipole-dipole; induced polarization; chargeability; resistivity; sedimentary.

1. **Introduction**

Minerals are naturally occurring homogeneous solid with a definite chemical composition and a highly ordered atomic arrangement; it is usually formed by inorganic processes [1]. Mineral exploration describes all the activities involved in the extraction of useful products from the rock formations of the earth [2].

Solid minerals in the Nigerian context are defined as all earth resources except for oil, gas and water. They include fuel minerals of coal, lignite and bitumen as well as the geomaterials of sand, gravel and laterite [3]. Solid minerals are very important to every nation. The weapons with which we wage wars and defend our national territory are derived from minerals, materials for housing, national and local infrastructure are derived from minerals. Technological machineries and inventions are made with minerals, the energy with which these machines are powered are derived from fuel minerals. Agricultural fertility is dependent on minerals and importantly human and animal health on the planet depend on solid minerals.

Nigeria is endowed with abundant mineral resources including gold, iron, lead, zinc, rare metals, coal and gemstones which could be harnessed for its development. These mineral deposits were formed at different stages in the geological evolution of Nigeria [4]. Figure 1.1 shows a map of Nigeria with the major mineral resources occurring in different locations of the country.

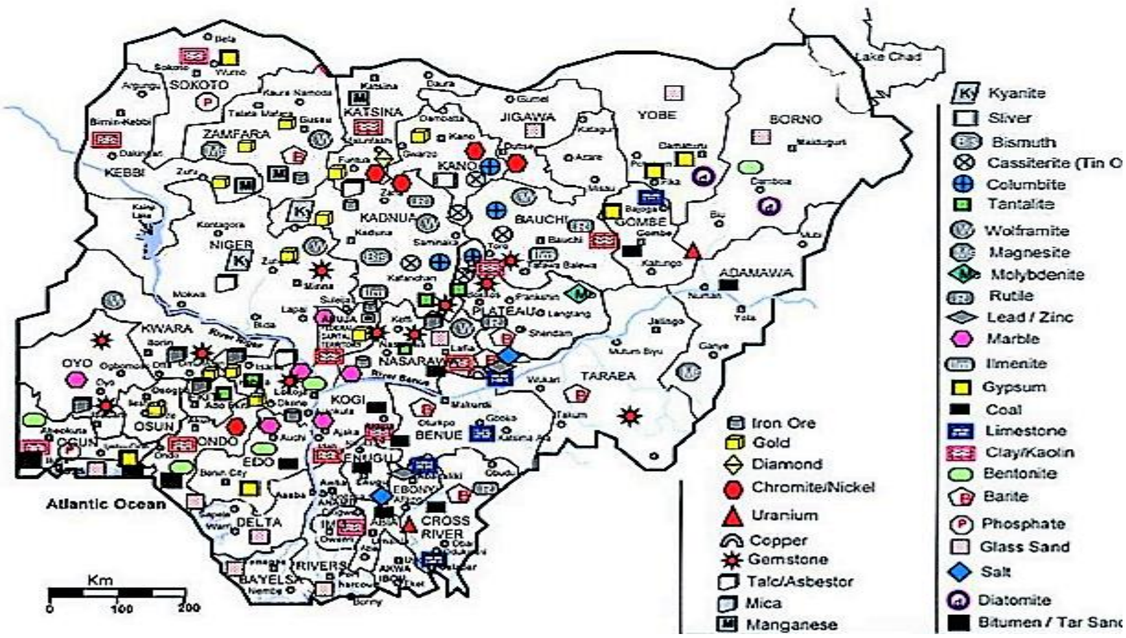

Figure 1.1 Map of Nigeria Showing the Distribution of the Major Mineral Deposits [5].

Mineral exploitation in Nigeria dates back to the geological expeditions by the colonial master in the early part of the 20th century. It has resulted in revenue accruing earnings and economic development, solid mineral exploitation is an everyday activity that is currently going on [6]. Sadly, despite these mineral endowment, the country's mineral sector has failed to meet public expectation of driving economic growth and generating employment to the teaming youth, largely because of poor information gathering with respect to these minerals and government over dependent on the oil sector for revenue generation. If the full potential of Nigeria's mining sector were to be unlocked, it will be a key driver to economic growth and development. Taraba state is one of the states in Nigeria that is well endowed with different kinds of solid mineral resources that is untouched and yet to be prospected [7].

Some of the prominent minerals in Taraba State include lead and zinc occurring in form of their ore, Galena and Sphalerite respectively [7]. Lead (Pb) is a relatively soft, malleable, blue-grey, heavy metal and is probably the earliest discovered metal that does not occur naturally in its pure state. Lead has a shiny chrome-silver lustre when it is melted into a liquid. Galena (PbS) is the principal ore mineral, usually found in association with sphalerite (ZnS) and barytes. Galena often contains inclusions of silver and is a major source of that metal [8].

Zinc (Zn) is a crystalline, bluish white metal that is brittle at most temperatures but becomes malleable between 100 and 1500C. Above 2100C, the metal becomes brittle again and can be pulverized by beating. It is principally mined as the primary sulphide sphalerite (ZnS), usually in association with galena and barytes. Sphalerite contains 67% Zn and often includes traces of simple sulphide such as Cadmium, Gallium, Germanium and Indium in solution [8].

1.1 Lead-Zinc occurrence in Nigeria

Nigeria is one of the Africa countries that are richly blessed with abundant natural resources and minerals and Lead-zinc are some of them; below are some of the states with Lead-zinc deposits; Akwa Ibom, Imo, Anambra, Bayelsa, Benue, Enugu, Niger, Ebonyi, FCT, Plateau, Cross River, Taraba, and Zamfara [9]. Figure 1.2 below shows the major lead-zinc occurrence distribution in Nigeria.

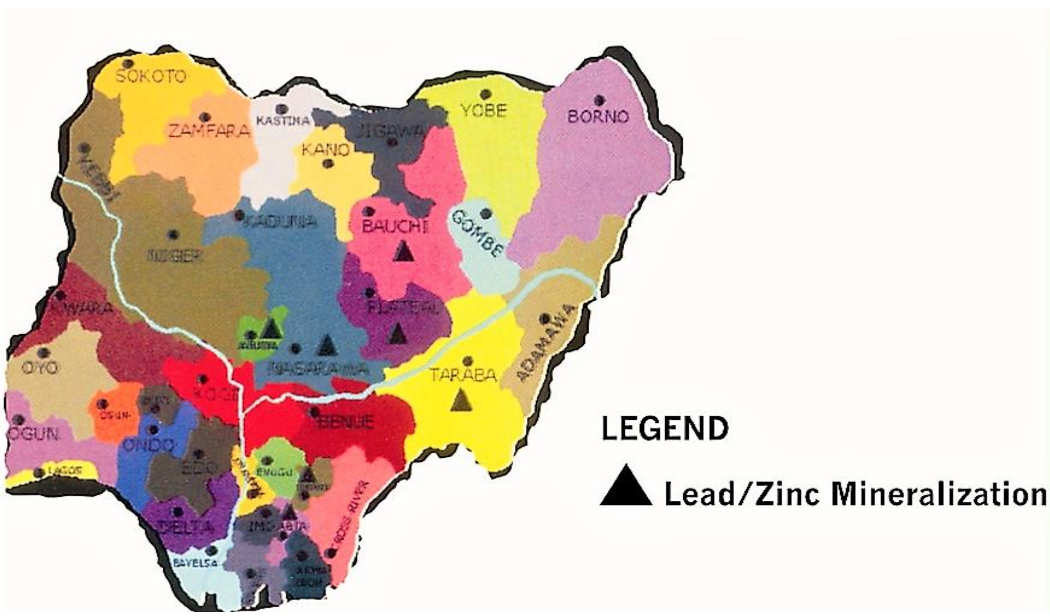

Figure 1.2 Map of Nigeria showing the Distribution of Lead/Zinc Occurrences [9]

Lead-zinc occurrences in Nigeria are reported to be associated with saline water intrusion in the sedimentary basins or fractured/shear zones in crystalline rocks [9]. The mineralization is often associated with minor to significant amounts of copper and silver. They are found occurring as lodes filling the fractures within the sedimentary rocks in the Benue Trough as well as in Crystalline Basement rocks. The Benue Trough, is believed to have originated as a failed arm of an aulacogen at the time of opening of the south Atlantic oceans during the separation of African plate and South American plate [5].

However, Certain mineral commodities such as base metals (e.g., lead, zinc) commonly occur together in similar geological situations, share a set of geological attributes, and contain a particular mineral commodity or combination of commodities, in the case of Lead-zinc, reports have it that its occurrence is in the form of disseminated forms across the country, which makes induce polarization which is a powerful geophysical tool a unique method usually adopted for the exploration and prospecting for these minerals, because for any geophysical exploration, the method usually adopted is dependent on the physical properties of the targeted bodies.

Exploitation of mineral resources has assumed prime importance in several developing countries including Nigeria. Mineral resources are an important source of wealth for a nation but before they are harnessed, they have to pass through the stages of exploration, mining and processing [10].

1.2. Location and Local Geology of the Study Area

The study area, Kambari is a town in Karim-Lamido local government of Taraba State, North eastern Nigeria. It lies between latitudes 6°25′N and 9°30′N and longitudes 9°30′E and 11°45′E. The geology and geological history of Taraba State is rather complex. Taraba State is underlain by Basement Complex and sedimentary rocks, each occupying a very distinctive part of the state. (Oruonye et al, 2011.) Figure 1.3 shows the map of the study Area.

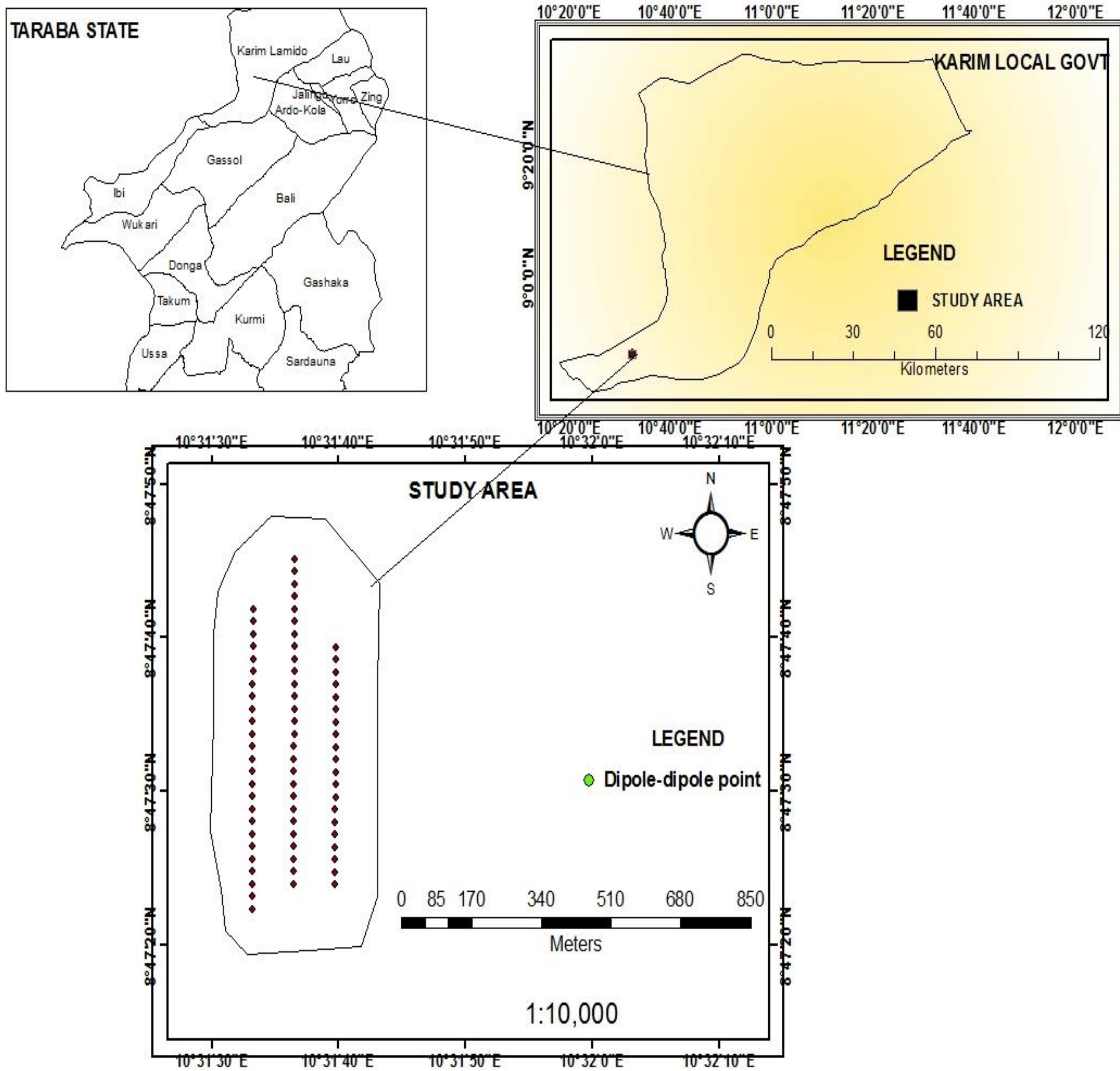

Figure 1.3 Map of Nigeria Showing Study Area

1.3 Topography, Vegetation and Geomorphology

The vegetation consists mainly of forest and tall grasses in the Southern part of the study area and interspersed by short trees in the north. It has the type of vegetation found in temperate regions with scattered short trees. It is marked by dry and rain seasons. The rain season commences in April, and lasts till October. While the dry season lasts from November to March. The average rainfall is 1.350mm. The Harmattan; dry, cold and dusty wind is the driest period and occurs from the months of December to February with humidity put at 13%.

The climatic, soil and hydrology of the Study area provide a conducive atmosphere for the cultivation of most staple food crops, grazing land for animals and fresh water for fishing as well as forestry.

The objectives of this research paper is to analyze, process and interpret the acquired IP data in terms of chargeability, resistivity and metal factor and generate chargeability, metal factor and the Resistivity pseudo-sections of the study area from induced polarization survey using dipole-dipole method.

2. Materials and Methods

An IP transmitter was used to introduces direct current pulses into the ground through the current dipole (C1 and C2). The pulses are in 2 seconds "on-off" time duration. The current dipole electrodes are hammered into the ground in a pit 0.5 – 1.0 m in diameter, equidistant from each other, and then interconnected with a thick copper wire. The pit is dug with a hoe, then moistened with salted water for better conductivity. The idea is to introduce as much current as possible into the ground, so one should lower the contact resistivity as much as you can. The IP receiver measures potential drop (voltage) in a potential dipole (P1 and P2). during the current transmission ("on-time"). The apparent resistivity value is calculated automatically based on the strength of the introduced current (I), the measured voltage (Vp), and the array coefficient, which depends on the mutual positions of C1, C2, P1, and P2. Figures 2.1a and 2.1b show the current and voltage electrons arrangements.

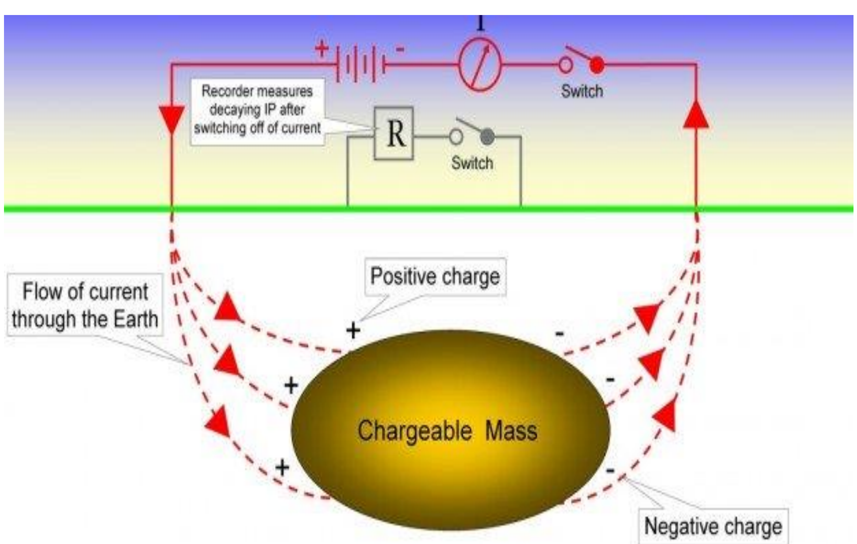

Figure 2.1a: Diagrammatic Representation of the IP Survey

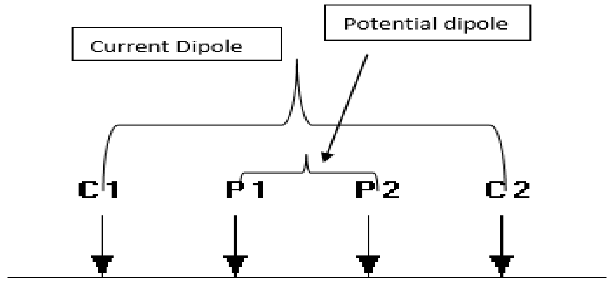

Figure 2.1b A conventional array with four electrodes showing the current and potential dipoles [11].

The receiver also measures the decay of the potential drop (induced polarization) in a potential dipole during the “off-time”; the chargeability value is automatically calculated as a ratio between the induced polarization measured during a specific part of the “off-time” (IP) and the initial voltage measured during the “on-time” (Vp). Measurements of the potential drop are performed with the use of pairs of non-polarizable electrodes (porous pots filled with saturated solution of copper sulfate). The porous pots are put into shallow pits (5-15 cm deep), moistened with 100-300 ml of fresh (unsalted) water for better contact. The IP receiver measures contact resistivity of each potential electrode;

2.1 Data Acquisition

The survey was carried out using the Time-Domain Induced-Polarization (TDIP) using a dipole-dipole configuration. The time domain is 2seconds for each stack and a total of 30 stacks are taken per reading. High current is injected into the ground through the current metal electrodes and the potential electrode receives the resistivity and chargeability values of the sub-surface. The chargeability and resistivity of the subsurface is measured using the eight potential electrodes (R_1-R_8), two current electrodes (TX_1 & TX_{II}) and a reference electrode (R_F).
The dipole-dipole spacing was 50m and the inter-profile spacing is 100m. Porous pots are used as potential electrode instead of metal electrodes. The porous pot contains copper (II) Sulphate pentahydrate (Cu2SO4.5H2O) solution and a copper rod. The Traverse line (1.4km) is drawn using a Global Positioning System (GPS) perpendicular to the generalized trend of the mineralization pattern in the study area, the base (Transmitter, receiver and Hand-Held computer are kept here) is about 600m from TX_I. The figure 2.2 below shows the data acquisition map of the study area.

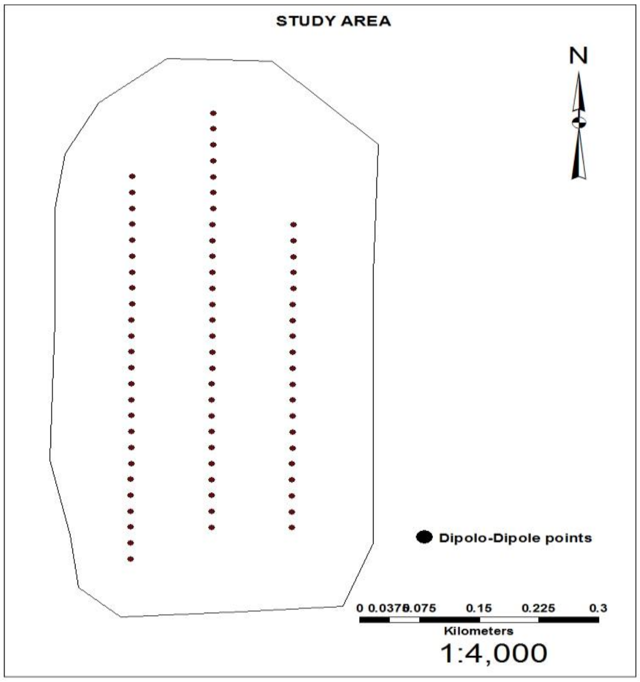

Figure 2.2 Data Acquisition map of the study area

2.2 Data Processing

The IP readings for each surveying day were downloaded to a computer and entered into a database on a daily basis. The acquired IP data were processed and plotted to generate 2-D pseudo sections showing the variation of the IP chargeability, resistivity and the metal factor coefficient computed by dividing the duo. Quality control of the acquired data was done using the Geosoft oasis Montaj IP module where the decay curve and the noise level of each channel are reviewed and noisy channels eliminated. The IP chargeability and resistivity data pseudo sections were plotted using the IP module of Oasis Montaj software. The software contours the IP chargeability values acquired at different depths and locations, and also assigns a color scale as defined by the user. The uppermost image is the IP chargeability plot, middle is the resistivity, while the lower section is the metal factor coefficient. This plot presents a vertical section showing the variation of IP chargeability and conductivity of materials at the subsurface along the survey profile. On the pseudo section, the high IP chargeability portions are in pink, while the low IP areas are in green-blue. In the resistivity section, the low areas are in blue, while the pink areas are the high resistive area. The metal content coefficient enhances structures that have high IP values and low resistivity by normalizing the IP values by the resistivity values.

3. Results and Discussion

3.1 Presentation of Results

A common method of presenting IP measurements is the pseudo section, in which readings are plotted so as to reflect the depth of penetration [12].

For this research, three traverses which varies in length ranging from about 600m to about 1.2km were mapped and each traverse was 100m apart. The results presented in form of pseudo sections showing the chargeability and resistivity variations of the subsurface along the traverses, and also as iso-maps showing the chargeability variations along the various traverses at different depths.

3.2.1 Pseudo-Sections

Figures 3.1 to 3.3 represent color coded chargeability and resistivity pseudo-sections of Traverses 1 2 and 3 respectively. Pink colour indicates very high chargeability and high resistivity zones, while the blue color indicates low chargeability and resistivity zones. High chargeability indicates probable conductive zones (possible lead zinc mineralization) while high resistivity indicates highly resistive units. The high chargeability area represents areas which are good targets for follow up.

3.2.1.1 Traverse 1

Traverse 1 is represented by figure 3.1, showing the chargeability, resistivity and metal factor Pseudo sections respectively, it is about 950m long and as already established, pink colour green colour, and blue colour depicts high, moderate and low respectively.

For this traverse, values ranging from about (7 to 29) mV/V depicts high chargeability, moderate chargeability ranges from IP values of (5 to 6) mV/V, while values ranging from about (-8 to 4) mV/V depicts low chargeability. In the same way, values ranging from (37 to277) Ωm depicts high resistivity, moderate resistivity ranging from about (31 to 36) Ωm while low resistivity ranging from

(16 to 30) Ωm. Also, values ranging from (89 to 550) $\times 10^{-3}$) Ω/m, represent high metal factor, moderate metal factor values range from about ((59 to 88) $\times 10^{-3}$) Ω/m while values ranging from ((-99to 58) $\times 10^{-3}$) Ω/m depicts low metal factor.

The depth at which the high chargeability and resistivity is evident is from about 200m – 350m, however there are also evidence of minor mineralization at shallow depths of about 100m – 150m.

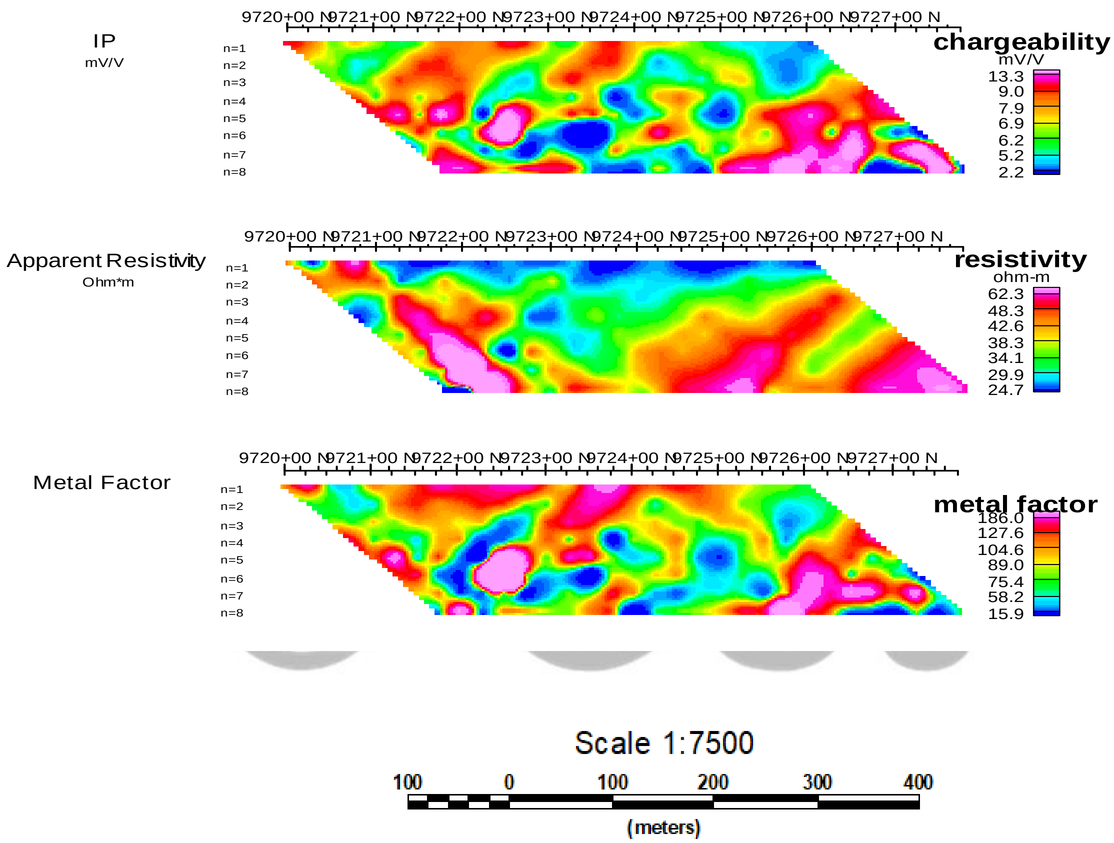

Figure 4.1 Psuedo-sections showing Chargeability, Resistivity and Metal factor variations in the subsurface along Traverse 1

3.2.1.2 Traverse 2

Traverse 2 is represented by figure 3.2, showing the chargeability, resistivity and metal factor Pseudo sections respectively, it is about 1.25km long and as already established, pink colour green colour, and blue colour depicts high, moderate and low for all the geophysical parameters being measured respectively.

For this traverse, values ranging from about (8 to 147) mV/V, depicts high chargeability, moderate chargeability ranges from IP values of (5 to 7) mV/V, while values ranging from about (-173 to 4)

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mV/V depicts low chargeability. In the same way, values ranging from (36 to 282) Ωm, depicts high resistivity, moderate resistivity ranging from about (28 to 35) Ωm, while low resistivity ranges from (3 to 27) Ωm. Also, values ranging from ((100 to 2996) $\times 10^{-3}$) Ω/m represent high metal factor, moderate metal factor values range from about ((56 to 98) $\times 10^{-3}$) Ω/m while values ranging from ((-53 to 54) $\times 10^{-3}$) Ω/m depicts low metal factor. The depth at which there is high chargeability is about from 150m-250m and high resistivity is evident from about 200m – 400m.

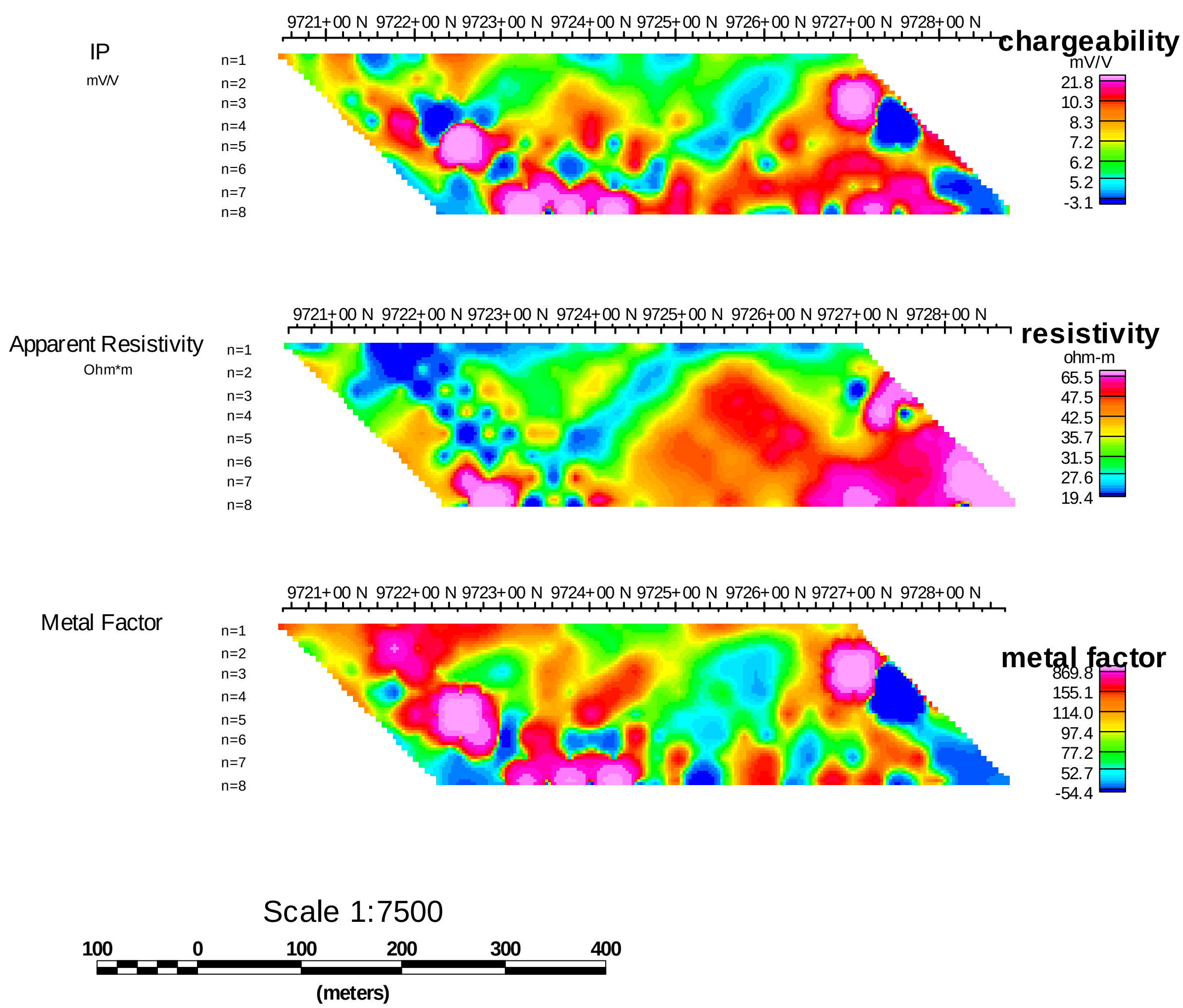

Figure 3.2: Pseudo-sections showing Chargeability, Resistivity and Metal factor variations in the subsurface along Traverse 2.

3.2.1.3 Traverse 3.

Traverse L667030 is represented by figure 4.3, showing the chargeability, resistivity and metal factor pseudo-sections respectively, it is about 975m long and as already established, pink colour green colour, and blue colour depicts high, moderate and low for all the geophysical parameters being measured respectively.

For this traverse, values ranging from about (8 to 288) mV/V, depict high chargeability, moderate chargeability ranges from IP values of (5 to 7) mV/V while values ranging from about (-142 to 5) mV/V depict low chargeability. In the same way, values ranging from (36 to 59) Ωm, depicts high resistivity, moderate resistivity ranging from about (30 to 35) Ωm, while low resistivity ranges from (12 to 34) Ωm. Also, values ranging from (93 to 3570) $\times 10^{-3}$) Ω/m , represent high metal factor, moderate metal factor values range from about (59 to 92) $\times 10^{-3}$) Ω/m while values ranging from (-907 to 58) $\times 10^{-3}$) Ω/m depicts low metal factor. High chargeability for this traverse can be traced to depth of about 250m-400m. the resistivity characteristics of this particular traverse can be said to range from low to fair and very high at a depth of 250m – 300m.

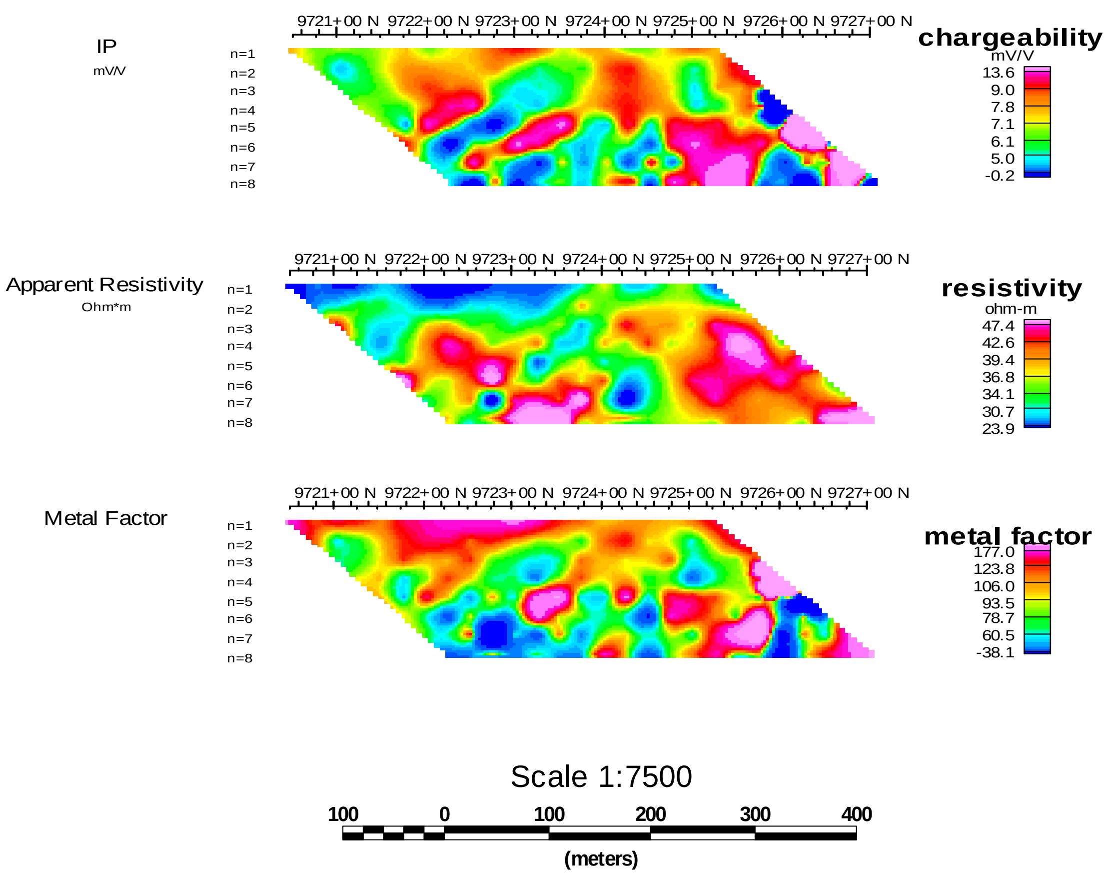

Figure 3.3: Pseudo-sections showing Chargeability, Resistivity and Metal factor variations in the subsurface along Traverse3

3.2.1.4 Stacked Chargeability Pseudo-Sections of Traverse 1 to Traverse 3.

According to figure 4.4, the stacked pseudo-sections shows the chargeability distributions of the four traverses surveyed as they extend from one traverse to the other showing area of possible mineralization potential.

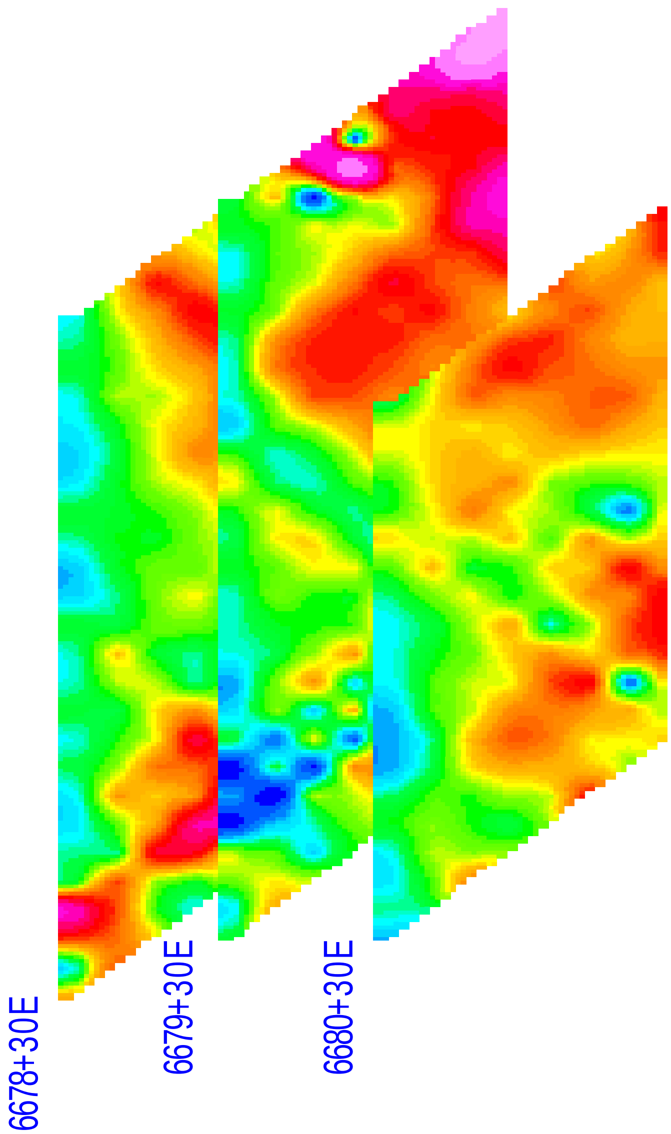

Figure 3.4 Stacked chargeability pseudo-sections showing the possible extent of mineralization across Traverse 1 to Traverse 3.

3.3 Iso- Contour Maps

Iso-contour maps showing Iso- chargeabilities and Iso- resistivities at various depth of probe (i.e. from n=1, 2,3...8) were generated for all traverses using surfer and Arc GIS.

3.3.1 Iso-Chargeability and Iso-Resistivity Maps.

The iso-chargeability and iso-resistivity distribution of the three traverses at various depths ranging from 50m – 400m (i.e. n=1 to n=8) were also presented as depth maps. This helps in revealing chargeability anomalous zones (areas with high chargeability values) and areas with anomalous resistivity (areas with low resistivity values), these areas were further used in delineating zones with potential mineralization, this was necessitated as a result of the geology of the study area which was largely observed to be unconsolidated sandstones from visible outcrops in the study area, this then means that the signature to expect was high chargeability values and low resistivity values. Figure 4.5 – Figure 4.12 show the iso- chargeability maps from n=1 to n=8 of the traverses in the study areas.

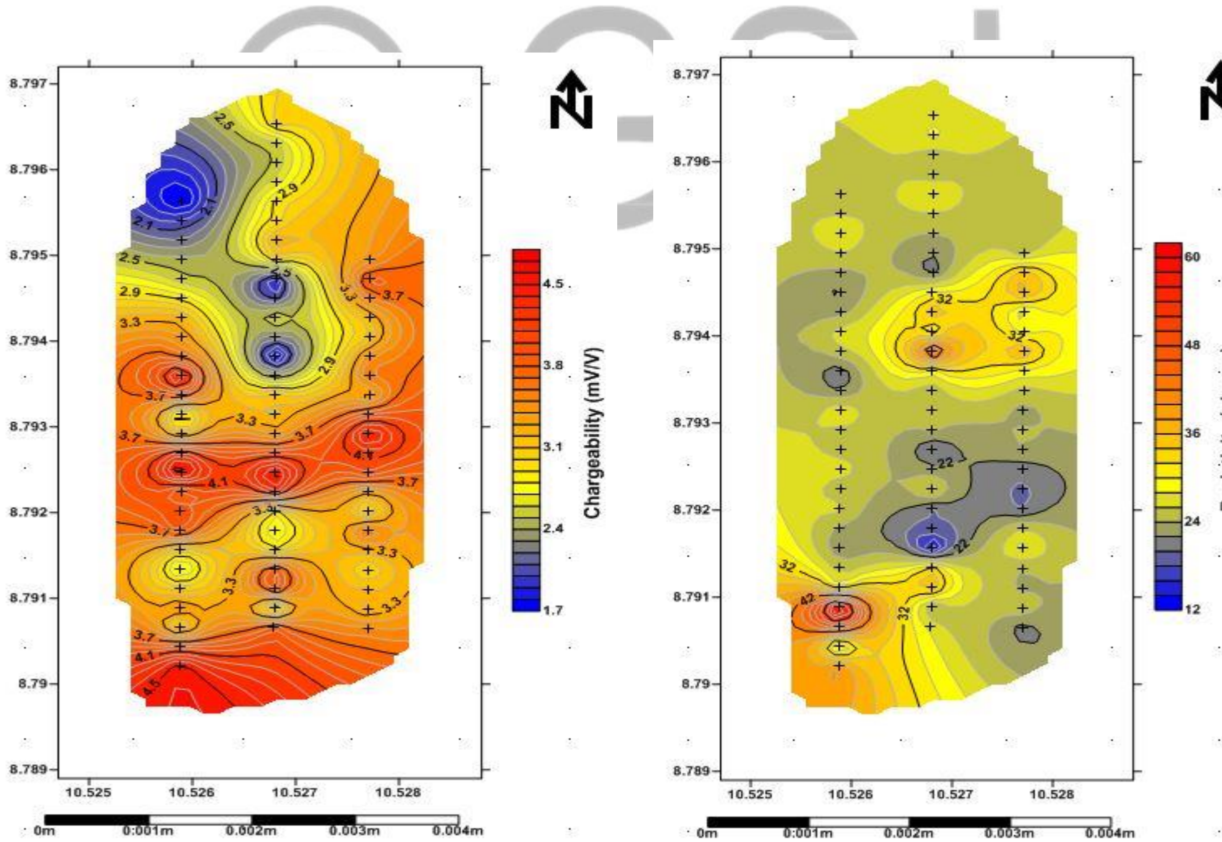

Figure 3.5: Chargeability and resistivity maps at n = 1

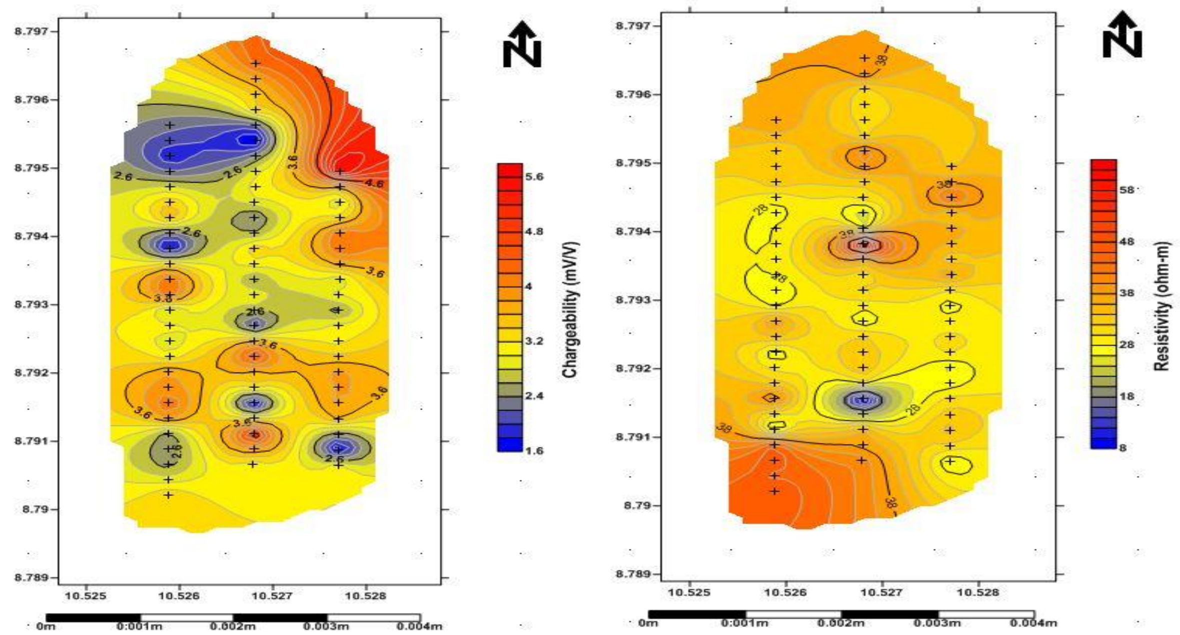

Figure 3.6: Chargeability and resistivity maps at n = 2

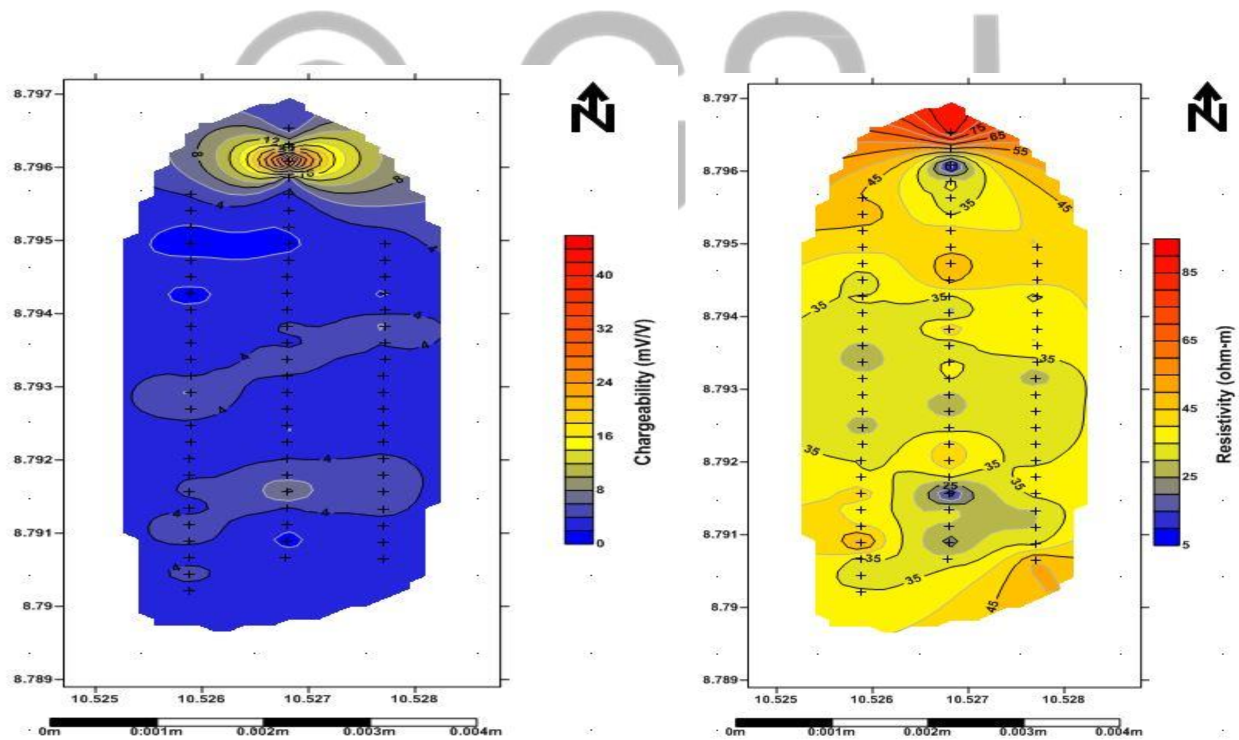

Figure 4.7: Chargeability and resistivity maps at n = 3

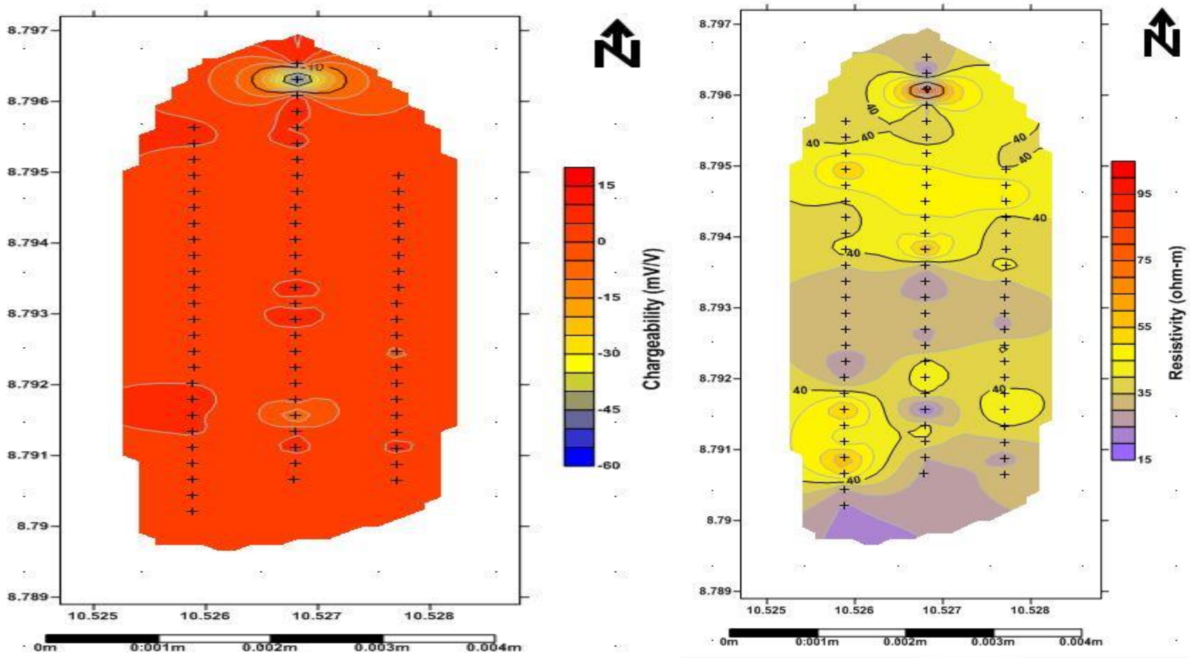

Figure 3.8: Chargeability and resistivity maps at n = 4

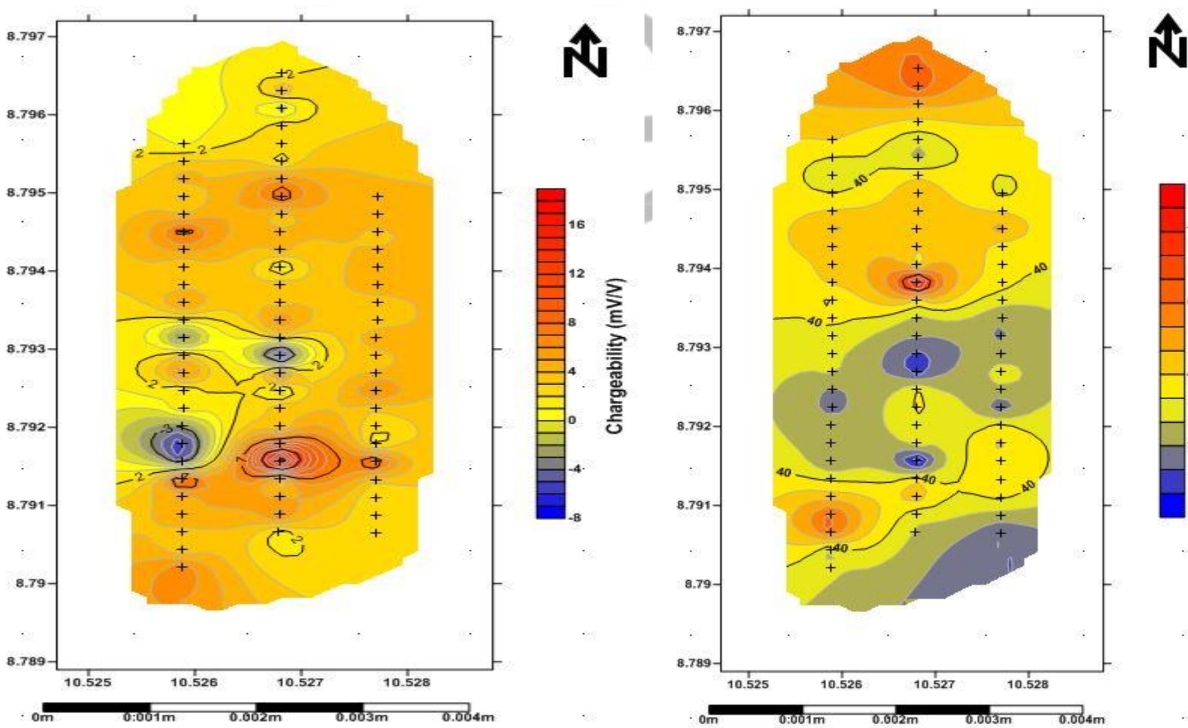

Figure 3.9: Chargeability and resistivity maps at n = 5

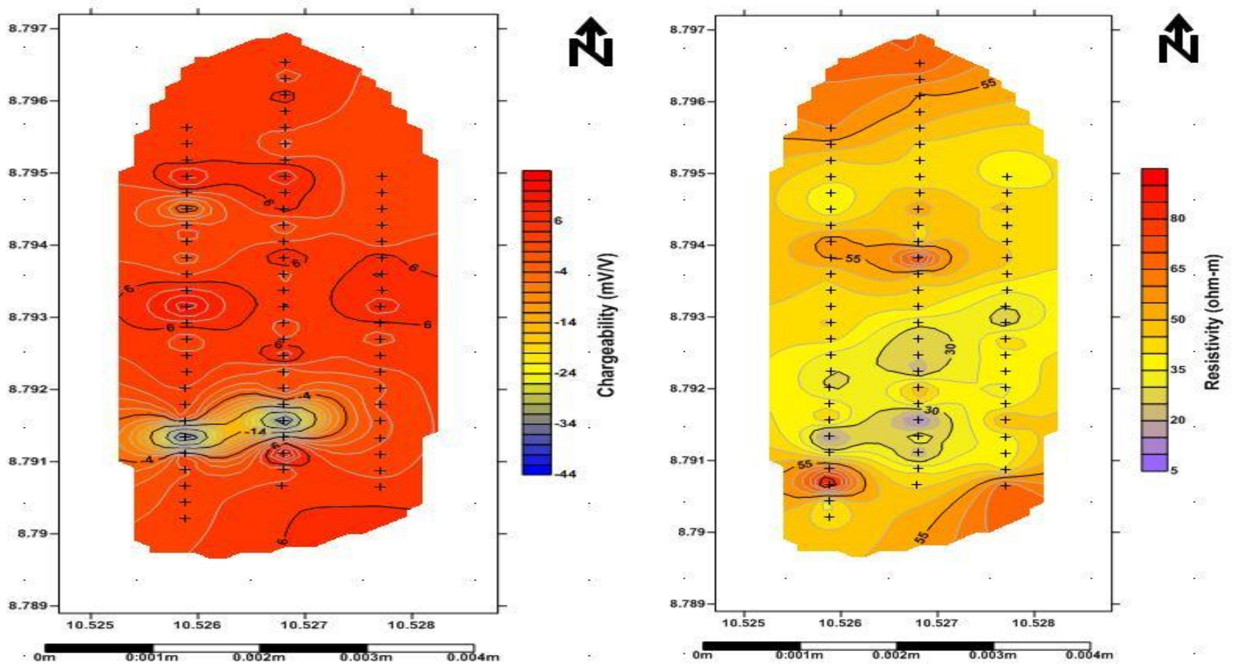

Figure 3.10: Chargeability and resistivity maps at n = 6

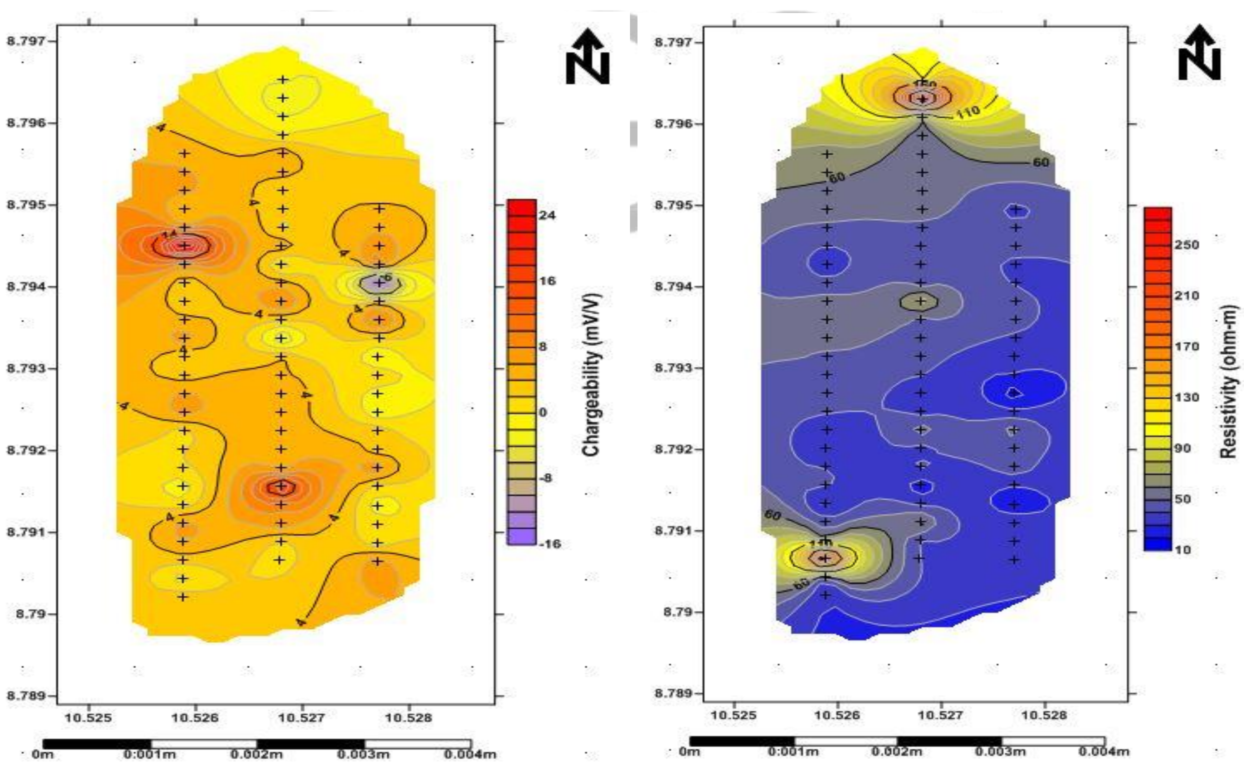

Figure 3.11: Chargeability and resistivity maps at n = 7

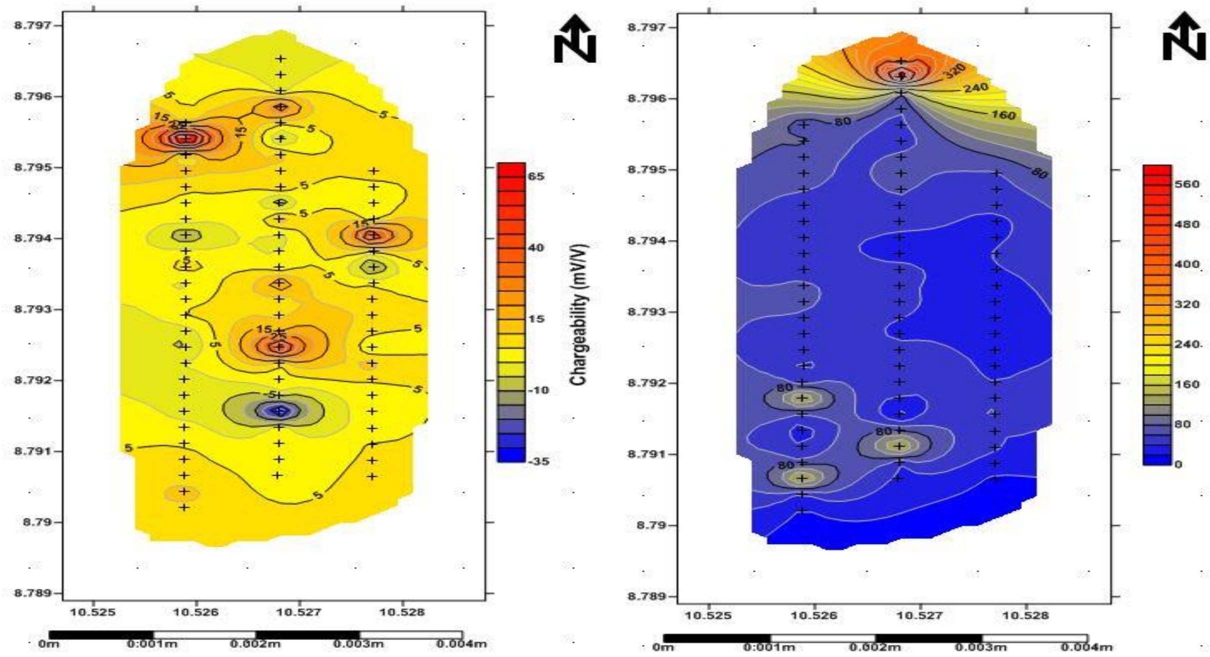

Figure 3.12: Chargeability and resistivity maps at n = 8

3.4 Summary of Results

The results from the pseudo-sections (figure 4.1- 4.3) and the contour maps (Iso-chargeability and Iso-resistivity) generated shows possible areas of mineralization occurrence. The pseudo-sections and map reveal that at n=1 to n=2 (i.e. from 50m to 100m) moderate chargeability and moderate resistivity zones. At n = 3 the area shows very low chargeability and moderate resistivity zones. From n=4 to n=6, there exist moderate to fairly high chargeability zones and corresponding moderate resistivity zones. At n=7 to n= 8, there were evidence of high chargeability and low to moderate and even high resistivity zones in the study area

The study area is underlined by sandstones and as seen from visible outcrops in the study area they were loose meaning they were unconsolidated and highly porous, and this means that the dominate signature to expect was low resistivity and high chargeability.

However, there were areas with moderate to high resistivity with corresponding high chargeability at deeper depth, this therefore means that the degree of compaction and cementation increases in in the depth of burial of the host sedimentary rocks such areas have not been fully exposed to geological activities such as weathering.

From the pseudo sections, it was observed that the dominate mineralized depth of the study area range of 200m-400m, this thus means the skipping ratio across the traverses is 200m.

In summary zones around n=4 to n=8 are all possible zones of lead-zinc mineralization in the study area and they are extended from one traverse to another (figure 4.4) in the study area and they are in consistent with the general trend of mineralization in the Trough.

4. Conclusion and Recommendations

4.1 Conclusion

Three traverses were selected and surveyed, this selection was done carefully reviewing past journals detailing reports on the lead-zinc mineralization of the study area. The three traverses were surveyed perpendicular to the general trends of mineralization in Nigeria and the study area adopting the induced polarization method. The acquired results from the IP surveyed were processed using Oasis Montaj, the processed results were then used to generate chargeability and resistivity pseudo-sections, and also iso-chargeability and iso-resistivity maps at various of the study area.

From the pseudo-sections and iso-contour maps generated, an average chargeability value greater than 10MV/V, was used in delineating areas having moderate to high anomalous (typical of Lead-zinc occurrences mineralization) zones at depths of about 200m-400m.

However, the Lead-zinc (Pb–Zn) mineralization in the study area display contrasting values in resistivity, chargeability, with regards to the sedimentary host rocks. Also, the non-fairly-well distributed nature of the mineralization further confirmed the nature with which they occur (i.e. mostly in disseminated forms).

In conclusion, although, the three traverses show evidence of Lead-Zinc occurrence, it is not sufficient to make any exploitation advise because the Lead-zinc mineralization in the study area shows that majority of the resources are not within economic drilling depths.

4.2 Recommendations

The study area shows evidence of mineralization, however, other mineral exploration methods like drilling and geochemical analysis, should be carried out to further confirm the occurrence of Lead-Zinc mineralization,

Secondly, the interpreted results from the pseudo-sections do not reflect the true nature of the subsurface, therefore inversions and advanced modelling are hereby recommended so as to get the approximate depth of occurrence of the mineralization, in case exploitation/ recovery activities are to be carried out in this particular study area.

Finally, from this study, exploitation and recovery of is recommended to be best mined through shafts and tunnels due to the dept.

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