Vol. 15(1), pp. 1-9, April-June, 2023
DOI: 10.5897/JGMR2022.0375
Article Number: 01080EC70603
ISSN: 2006-9766

http://www.academicjournals.org/JGMR

Journal of Geology and Mining Research

Full Length Research Paper

Assessment of depth to Lead-Zinc deposit in parts of Southern Benue Trough using integrated geophysical methods

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Received 31 July, 2022; Accepted 24 January, 2023

This study employed the techniques of electrical resistivity, induced polarization and aeromagnetic methods to investigate and quantify lead-zinc ore deposits. The electrical methods of geophysical exploration were employed to measure thickness of overburden as well as width of the ore across the study area. IP method was used to investigate dissemination of lead-zinc sulphides. Aeromagnetic data over the area was acquired and processed to detect lead-zinc lode as well as magnetic anomalies present in the study area. This study reveals that there is a lead-zinc lode along the investigation area. This lode was delineated clearly through the magnetic anomaly signature of an aeromagnetic data over the area. IP survey results and imaging agrees with the aeromagnetic signature of the lode both in trend and width. Vertical electrical sounding, Schlumberger array determined the varying overburden thickness between 20 to 44m across the lode. These techniques have been helpful in discovering and/or delineating lead – zinc ore deposits but it is suggested that shafting, trenching and core drilling be used as a comparative study.

Key words: Assessment of Lead-Zinc deposits, Magnetic anomalies, Aeromagnetic data.

INTRODUCTION

Lead-zinc occurrences in Nigeria, especially in Southern Benue Trough (study area) are reported to be associated with saline water intrusion in the sedimentary basins or fractured/shear zones in crystalline rocks (NGSA, 2019). Lead-zinc mineralization in the upper Benue Trough is confined to well-defined steeply dipping fractures and faults striking in an N-S direction. A close examination of the mineralized structures of abandoned mine workings revealed that the strike length of the veins varies from a few meters with thickness ranging from a few centimeters to two meters. The most abundant sulfide mineral is sphalerite which occurs in two forms,- a massive reddish-brown type and a dark brownish-black variety. Galena which is generally subordinate to sphalerite in relative abundance occurs either as perfect cubes or as inter-granular crystals within the late dark brownish black sphalerite. Chalcopyrite occurs as a minor sulfide. The commonest hydrothermal gangue minerals are quartz and siderite. Most of the siderite has been dissolved and re-crystallized as hematite (Ogundipe, 1987). Farrington (1952) recorded that the first production of the lead-zinc ore from the mine was in 1925 as systematic mining

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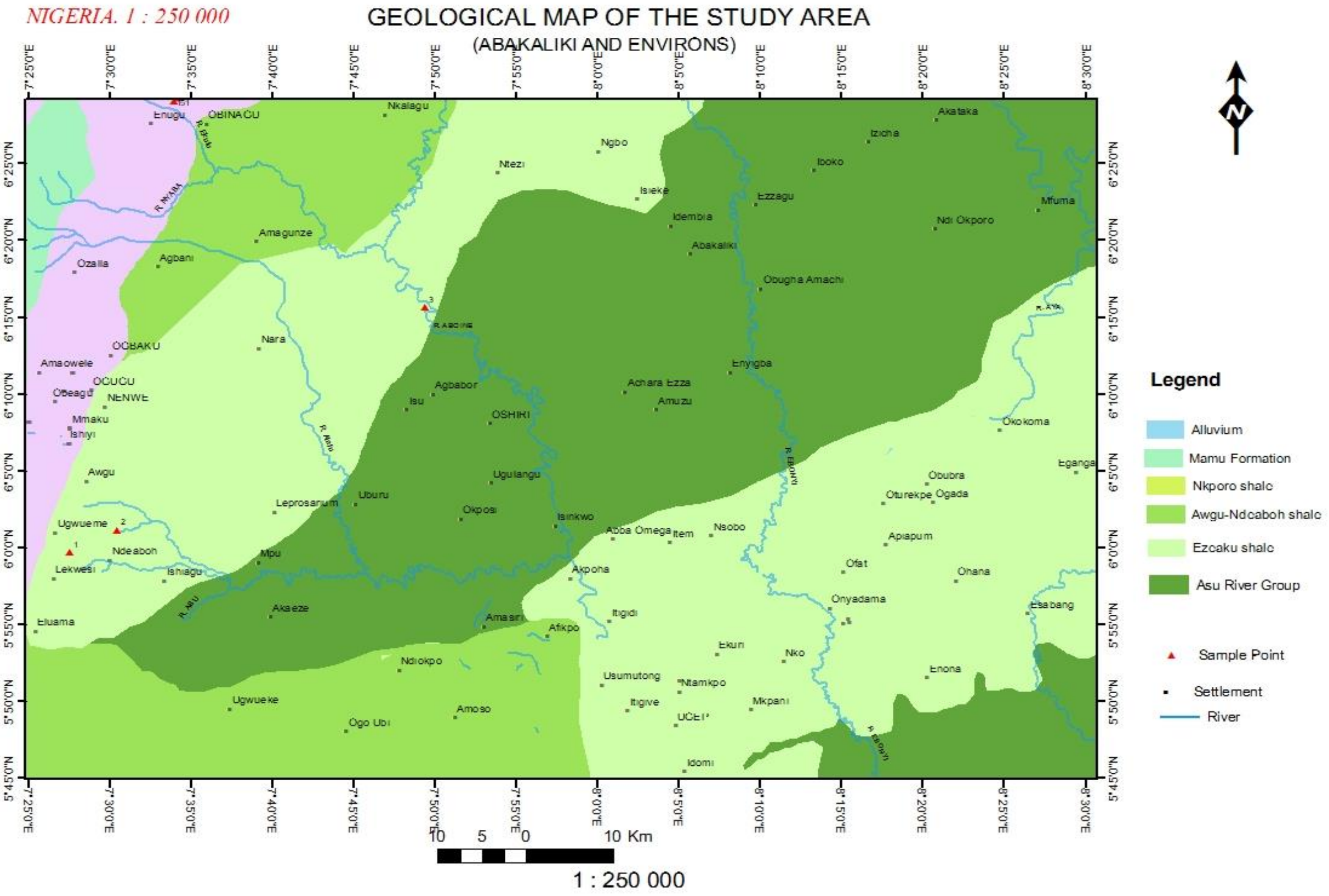


Figure 1. Geological map of Abakaliki and environs (parts of the study area).
Source: modified after NGSA, 2006

started shortly before the world war (July 1914 to November 1918). However mining ceased at the onset of the civil war (1966). Nwachukwu (1972), Orajaka (1965, 1972), Olade (1975, 1976) and Farrington (1952) noted that mineralization is hydrothermal and epigenetic in origin which formed at mesothermal conditions. Although mining of the lead-zinc ores commenced in all districts as early as 1925, the upper Benue deposits have been relatively less studied. Most of the studies were centered on the geology and origin of the lower Benue lead-zinc-copper deposits but which was always projected to the upper Benue Trough Zurak-Wase lead-zinc deposits (Umar et al, 2011.). Thus, this study is aimed at determining the thickness of the overburden so as to guide prospective investors. The magmatic-hydrothermal model (Farrington 1952, Orajaka 1965 and Nwachukwu 1975) was based on the morphology and epigenetic characteristics of the veins. The Juvenal and connate brines model proposed by Offodile (1976), suggests interaction between juvenile solutions and connate brines. The circulating connate brines model (Grant, 1971; Olade, 1976; Olade and Morton, 1985) relies mostly on fluid inclusion data, mode of occurrence and geological settings of the lead-zinc ores.

GEOLOGICAL SETTING GEOLOGIC SETTING OF THE STUDY AREA

The study area (Figure 1) is located within Benue Trough. According to King (1950), Farrington (1952), Nwachukwu (1972) and Murat (1972), the Benue Trough originated as a failed arm at the time of the opening of the South Atlantic Ocean during the separation of the African plate and the South American plate. Benue Trough is defined as an intercontinental cretaceous basin about 1000 km in length stretching in NE-SW direction and resting uncomfortably upon the Precambrian basement. Based on the trough corresponding geological and geomorphologic partition, it is subdivided into the upper, middle and lower region. The lower which is the southern Benue Trough, is the southwestern part of the Benue depression (Carter 1963; Reyment, 1965). It comprises of the Abakaliki Anticlinorium, Afikpo Synclinorium to the east and Anambra Basin to the west. The first marine transgressive phase in the middle to late Albian resulted in the deposition of the Asu River Group sediment. Its lithostratigrahic pile includes sandstone, siltstone, shale and limestone occurrences, Reyment (1965). The occurrence of lead-zinc deposit in SE Nigeria is dominantly restricted to the Albian sediments, Nwachukwu (1972). Wright (1968) noted that the lodes were developed at the end of Santonian folding.

MATERIALS AND METHODS

Electrical and magnetic methods of geophysical surveys were employed in the quantitative assessment of lead-zinc deposits in some parts of Southern Benue Trough. The study area covering about $2.25km^2$ was gridded into profile lines, each profile line 100 meters apart from the other and 1.2 km in length respectively. On each profile line, Wenner array was utilized to investigate apparent resistivity variation of the subsurface. The instrument used during this work is ABEM Terrameter SAS 1000, four electrodes, and four connecting wires of varying length. Readings from Terrameter were taken, stored and later retrieved for analysis. Thereafter contour lines were drawn to locate points of equi-apparent resistivity. The most important electrical property of subsurface structure is due to the electrical resistivity changes, otherwise known as specific electrical resistance and apparent resistivity. When electrical current is passed into the ground, the magnitude and distribution of current lines in the subsurface are mostly dependent on effective electrical resistivity of the subsurface of the study area. The magnetic data used in this project was obtained from the Nigerian Geological Survey Agency on a scale of 1:100 000. The data was acquired in 2009. The data was obtained along a series of NW – SE with a flight line spacing of 500m and tie line spacing of 5 km. The flight line direction is in the direction of 135° azimuth and the tie line direction is in 45° azimuths. The flying altitude was 80m above the terrain. The average magnetic inclination and declination across the survey was 9.75° and 1.30° respectively. The projection is WGS 1984. The geomagnetic gradient was removed from the data using the International Geomagnetic Reference Field formula (IGRF) of 2008. The analytic signal or total gradient (Nabighian 1972, 1974 and 1984) is formed through the combination of the horizontal and vertical gradients of the magnetic anomaly. The analytic signal has a form over causative body that depends on the locations of the body (horizontal coordinate and depth) but not on its magnetization direction. This quantity is defined as a complex function that its real component is horizontal gradient and its imaginary component is vertical gradient which can be proven that imaginary component is Hilbert transform of real component.

The amplitude A of the analytic signal of the total magnetic field T is calculated from the three orthogonal derivatives of the field according to the formula of Roest et al. (1992). The Source Parameter Imaging (SPI) function is a quick, fast, useful, and powerful method for calculating the depth of magnetic sources. Its accuracy has been shown to be +/- 20% in tests on real data sets with drilled hole control. This accuracy is similar to that of Euler deconvolution, however SPI has the advantage of producing a more complete set of coherent solution points and it is easier to use. A stated goal of the SPI method (Thurston and Smith, 1997) is that the resulting images can be easily interpreted especially with a sound knowledge of the geology. The SPI method (Thurston and Smith, 1997) estimates the depth from the local wave number of the analytical signal.

RESULTS AND DISCUSSIONS

The 2-D resistivity structure shows variation in layer resistivity across the measured field. A lead-zinc deposit has high conductivity but low resistivity. Thus, areas of low resistivity indicate deposits as represented in Figure 2. The Vertical Electrical Sounding (VES) conducted at various points revealed overburden thickness varying from about 21.22 m (70.03 ft) to 44.4 m (146.2 ft) as shown in Figure 3. Thus, the deposits start from about 21.2m and continue deep down the subsurface. The 2-D resistivity structure and magnetic anomaly signature agrees with VES results. The resistivity and magnetic anomaly indicates lead-zinc lode reasonably thick down the subsurface. The chargeability of galena is about 3.7 ms, this agrees with the results of Induced Polarizations results conducted in the area as shown in Figure 4a and 4b.

Qualitative technique in aeromagnetic data interpretation is centered on analyses of trends and lineaments. These were analyzed qualitatively and quantitatively. Trends were analyzed using profiles or gridded data and generally consist of lines on a map that may correspond to edges of structures, faults, or partitions of the data character. Several magnetic lineaments were inferred from vertical derivatives, and analytical signal maps (Figure 7). The dominant structural trends of the lineament was identified in the study area, it trends in the northeast-southwest direction. This trend is consistent with the major structural trend of the Basement Complex of Nigeria. These results are in agreement with those from previous geophysical and geological studies in the area (Ojo, 1990). It is inferred that the northeast-southwest trending Chain fracture zone passed through the study area. The linear structures running northeast-southwest observed from the study area were suggested as the continental extension of the Pre-Cretaceous oceanic fracture zone; that is the Chain and Charcot Fracture Zone which runs along the trough axis beneath the sedimentary cover. Furthermore, the landward intersections of the lineaments may have influenced the formation of the drainage pattern. Thus, suggest that lead-zinc mineralization pattern of the study area is structurally controlled. The depth to the basement source and thickness of sediments were determined from Euler Depth and Source Parameter Imaging (Figures 8 and 9 respectively). Generally, basement depth ranges from 0.55 to 4.49 km in the study area. These depth methods of depth determination employed showed a very good similarity of results. The deepest depth of 4.49 km represents the magnetic rocks that were emplaced or intruded into the basement surface underlying the basin. It may also be due to the presence of intra-basement features such as fractures and faults. These deepest depths thus represent the depth to the deeper magnetic source. Interpretation of the depth maps show the basement rock is faulted and there is a good correlation in trend and location between basement structures, and trends, and overlying sedimentary fault systems. These positive correlations strongly suggest that the sedimentary section has been influence by the underlying basement

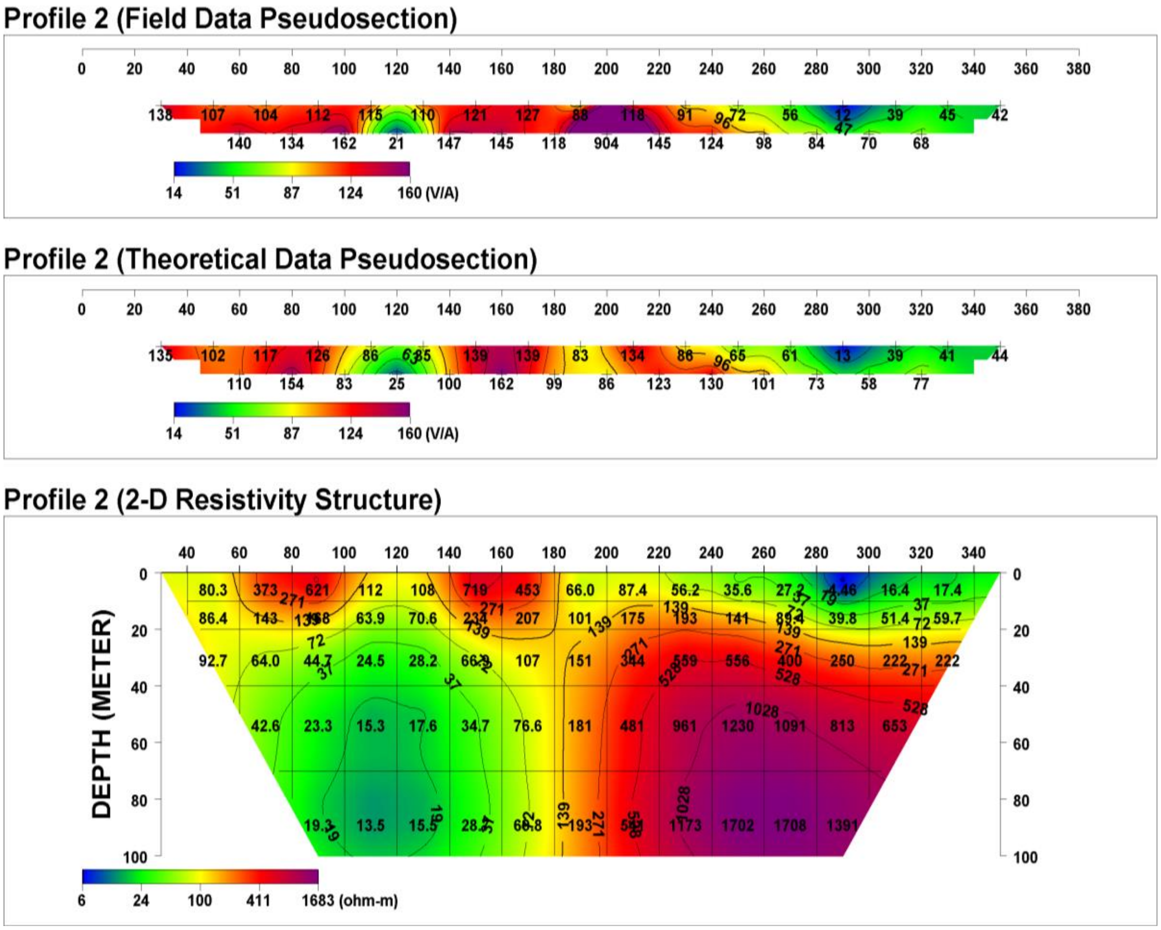
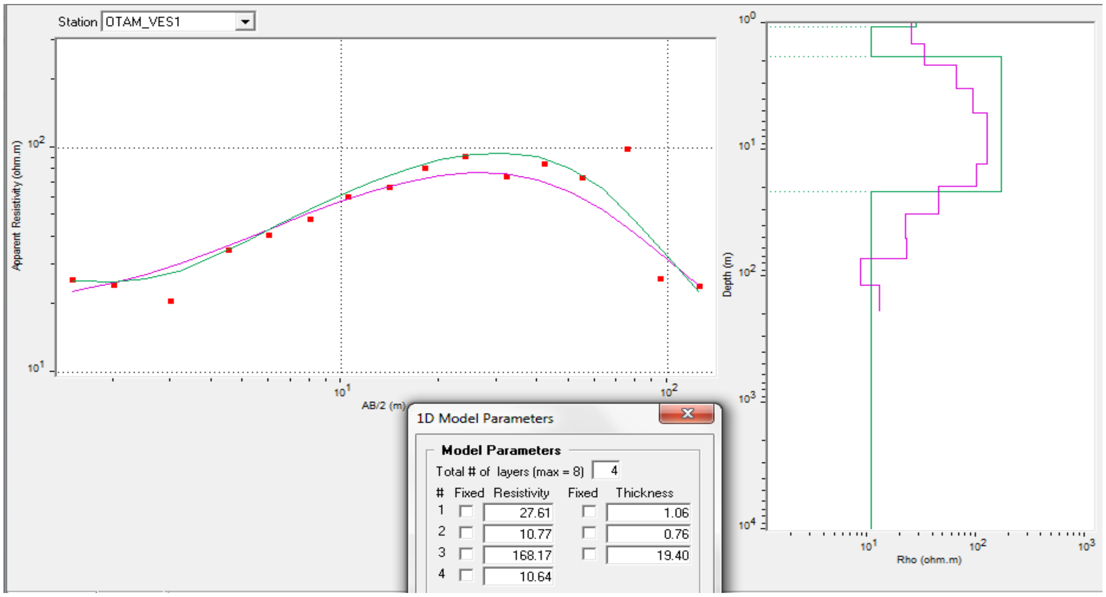


Figure 2. representative of the 2-D resistivity structure.
Source: Author, 2022



Station OTAM_VES1

1D Model Parameters

Model Parameters

Total # of layers (max = 8) 4

#	Fixed	Resistivity	Fixed	Thickness
1	☐	27.61	☐	1.06
2	☐	10.77	☐	0.76
3	☐	168.17	☐	19.40
4	☐	10.64		

Figure 3. representative of the VES modelled section.
Source: Author, 2022

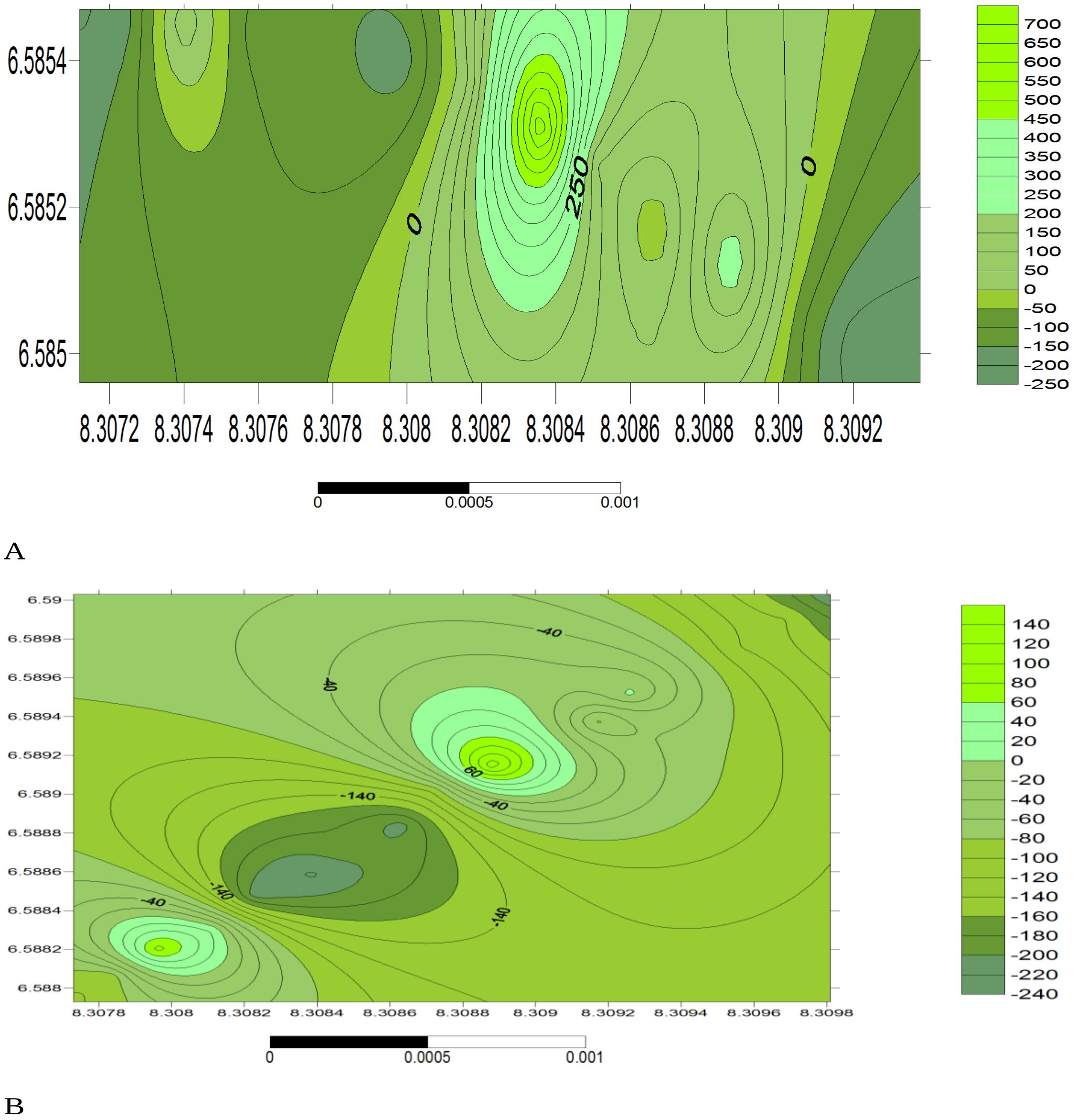


Figure 4. a: Induced polarisation maps of the study area; b: Induced polarisation maps of the study area.
Source: Author, 2022

architecture. The fractured areas (Figures 5 and 7), especially the pinkish to reddish colors are suspected to be lead-zinc lode. This is further confirmed by the lead-zinc deposits revealed in the active mining pits (Figure 10) within the study area with similar magnetic signature (Figures 5 and 6).

CONCLUSION

Lead-zinc mineralization in the Southern Benue Trough of Nigeria has been studied by several authors in the past. This present work is to determine the thickness of the overburden so as to elucidate the quest of prospective investors and spur them into actions for economic benefits of the nation. The thickness of the overburden were determined using vertical electrical sounding (electrical methods) of geophysical surveys. The thickness ranges from 20 to 44 m across the investigated area. The depths to the basement source, thickness of sedimentary pile up were determined from source parameter imaging. Generally, depth to basement source ranges from 0.55 to 4.49 km in the study area. The deepest depth of 4.49 km represents the magnetic rocks that were emplaced or intruded into the basement surface underlying the basin. It may also be due to the presence of intra-basement features such as fractures and faults. These deepest depths thus represent the

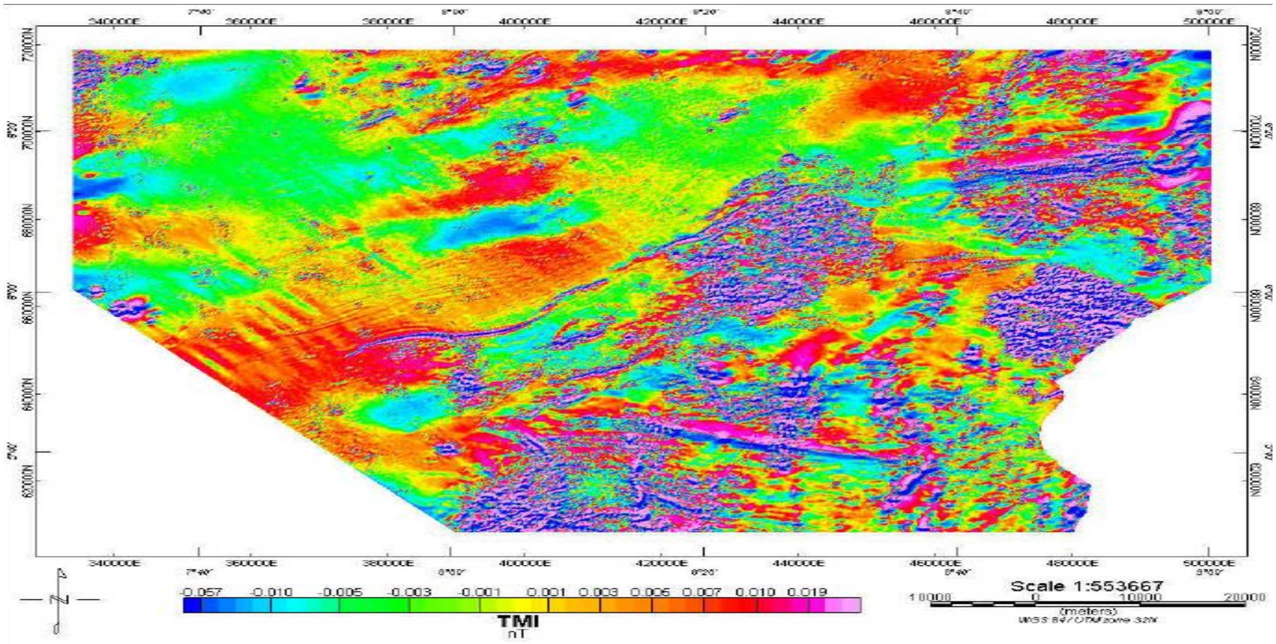


Figure 5. Total magnetic intensity map of the study area.
Source: Author, 2022

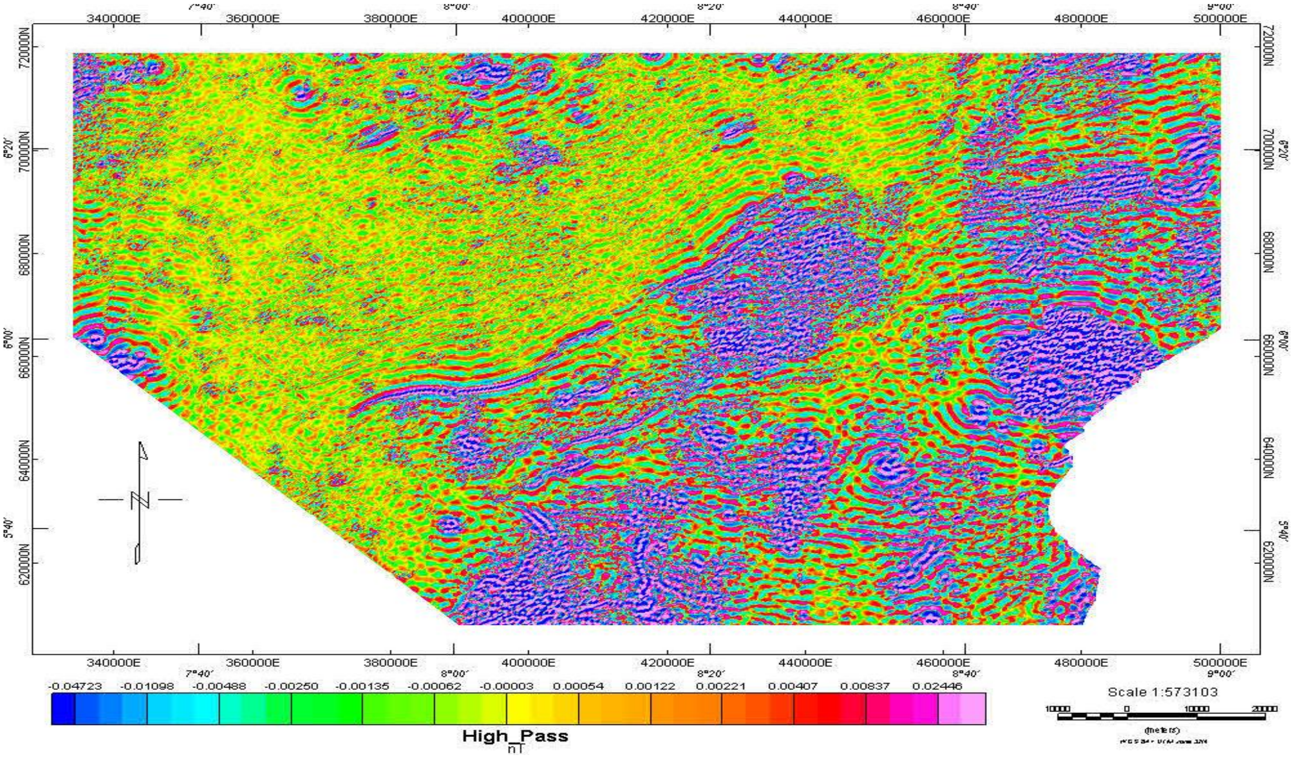


Figure 6. Residual map of the study area.
Source: Author, 2022

depth to the deeper magnetic source. These deep basement regions are most likely rich in matured sediments and tectonically deformed for lead/zinc mineralization. Areas of parallel fractures or regional

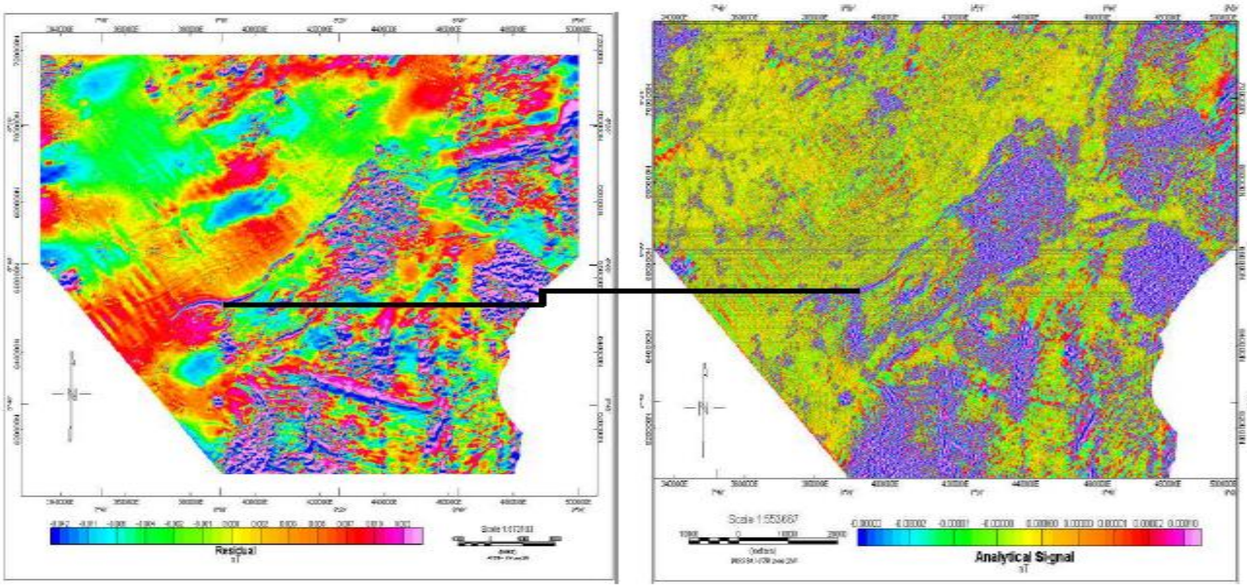


Figure 7. The Chain regional fracture in residual map and analytical map respectively.
Source: Author, 2022

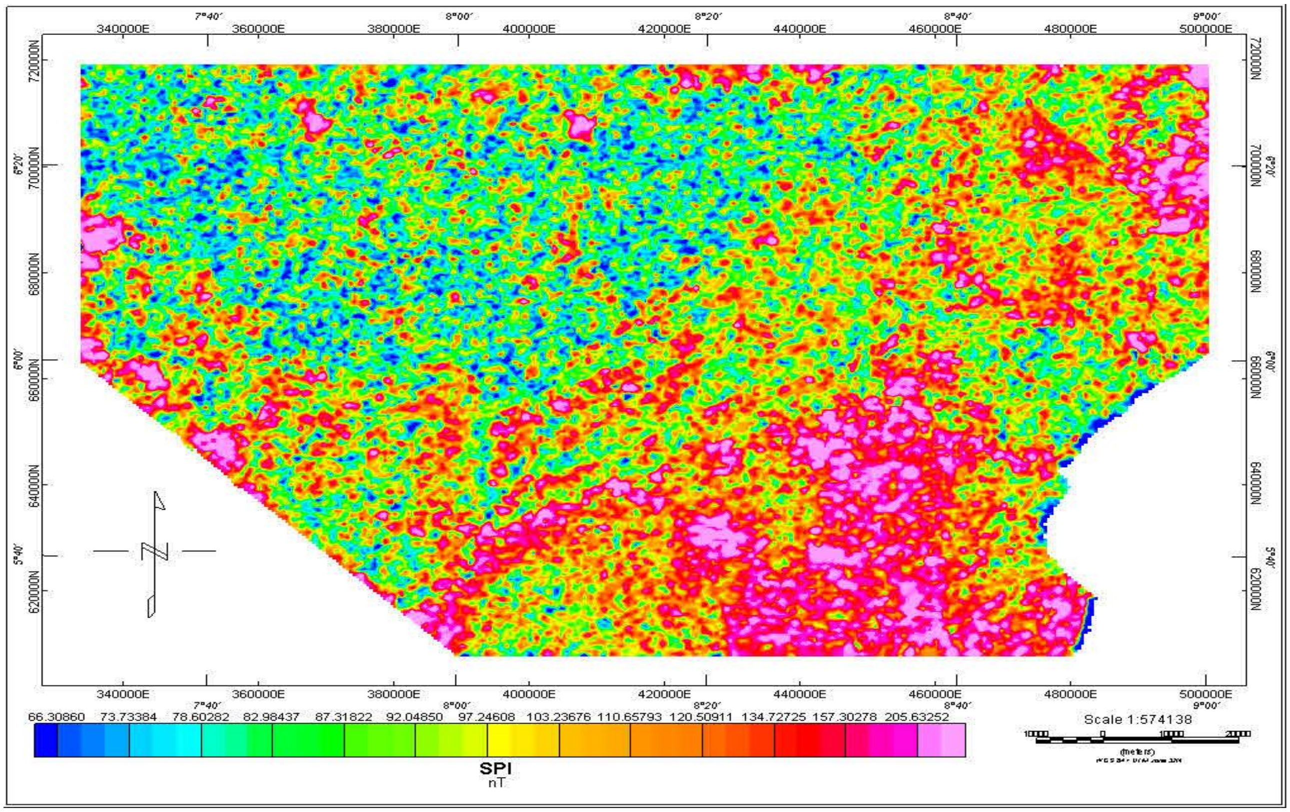


Figure 8. Source parameter imaging map of the study area.
Source: Author, 2022

fractures are good targets for lead/zinc prospecting. Igneous instrusions are identified within some of the study area which is expected to be pegmatitic and thus, precursors for mineralization. Thus, the Abakaliki area

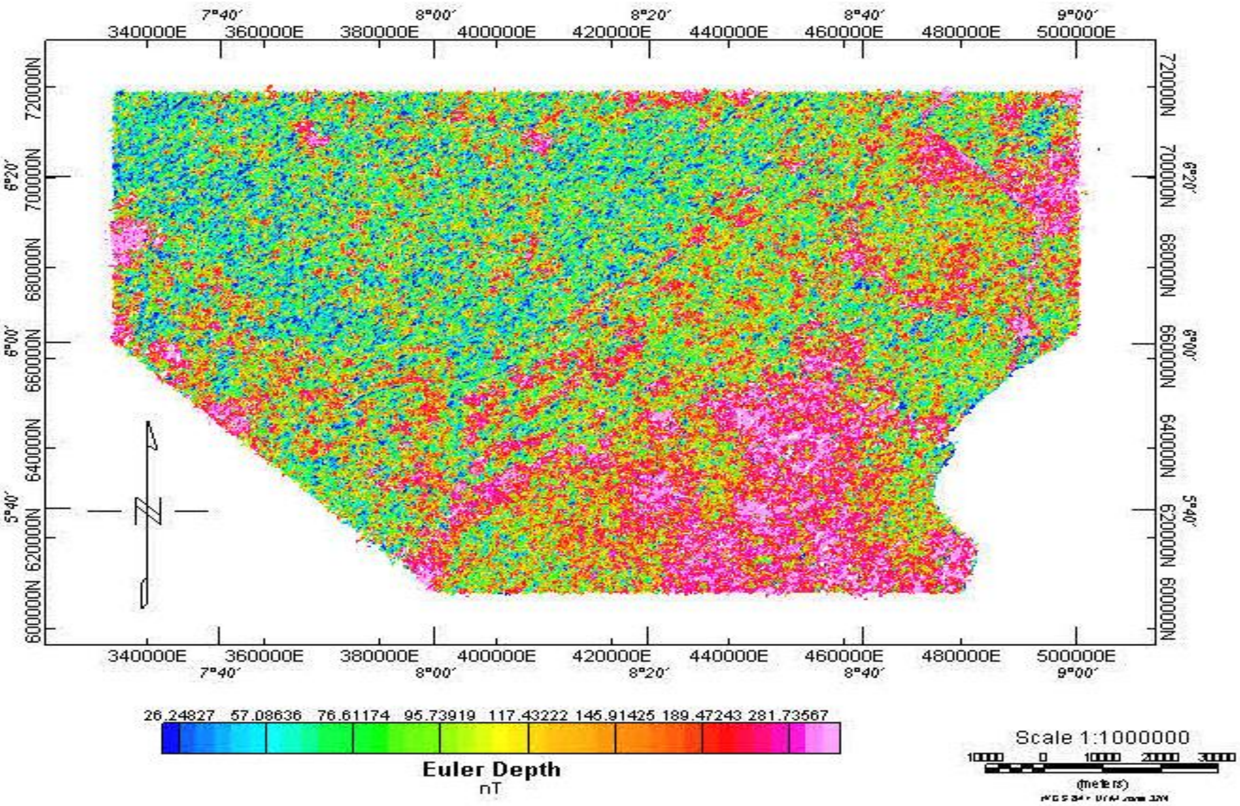


Figure 9. Euler Depth Map of the Study area.
Source: Author, 2022

Figure 10. A lead-zinc mining pit in Enyigba, Ebonyi State, Nigeria (part of study area).
Source: Author, 2022

with extrusive rocks and well deformed are strategic area for mineral prospecting.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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