



SUBSURFACE INVESTIGATION FOR TANTALITE MINERALIZATION USING MAGNETICS AND ELECTRICAL RESISTIVITY METHODS, (IN SEPETERI, OYO STATE, NIGERIA)

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AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Received: 05 September 2021

Accepted: 10 November 2021

Published: 15 December 2021

Original Research Article

ABSTRACT

The study aims to map the depth of the tantalite mineralization as well as its location around the Olorunda mining site using integrated geophysical methods. Eight (8) profiles were conducted for the magnetic survey using G-856AX proton magnetometer in E-W direction with a total of 158 data points, profile length of 190 m, 10 m station spacing, and 20 m profile spacing. Six (6) vertical electrical soundings (VES) data points were measured on the points that have high magnetic susceptibility using the Schlumberger array configuration of the electrical resistivity techniques with a spread of 100 m. The anomaly map has a range of 19nT to 78nT for the magnetic intensity which depicts the area of magnetic susceptibilities. The Reduced to equator anomaly map has a range from 16.6nT to 77.4nT for the magnetic intensity which depicts the area of magnetic susceptibility directly above the sources. The first vertical derivative (FVD) map has a range from -1.69nT to 1.89nT. The source parameter imaging depth (SPI) map has a range from 4.3 m to 20.9 m. The total gradient map has a range of from 0.31nT/m to 3.30nT/m. The elevation map has a range from 349 m to 372 m. The high magnetic areas are in the southwestern, west, central, and eastern parts of the Olorunda mining site. The resistivity values of the study area range from 121 Ω m to 2500 Ω m. The low resistivity values reveal high conductivity areas of the study area, as a result of the pegmatite rocks around the mining site. The VES reveals the depth of tantalite mineralization at 35.8m, 44.3 m, 55.1 m, 42 m, 46.5 m, and 4.18 m.

Keywords: Tantalite; first vertical derivative; source parameter imaging; vertical electrical-sounding.

1. INTRODUCTION

Throughout the history of civilization, the surface of the earth has supplied the setting for the majority of human activities, and these activities have been profoundly influenced by the generally unseen characteristics of the near subsurface. Resources obtained from both near-surface and deep-sea sources have had a significant impact on human development.

(as in construction materials) and hundreds to thousands of meters deep (as in metalliferous ores and petroleum-based products) [1]. We also use water from subsurface aquifers for industrial and residential uses; we dispose of much of our garbage in the near subsurface; and we construct structures that must safely interact with these shallow areas [2,3]. Subsurface features of particular importance to earth scientists concerning these operations include rock

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type location, distribution, depth, and structure, grain size distribution and material strength, porosity, and permeability, to mention a few. Because of the earth's inherent complexity, inferring these features through direct observation can be difficult or impossible. As a result, they must frequently be inferred from the distribution of more basic physical attributes including density, electrical conductivity, magnetic susceptibility, and acoustic impedance. Geophysical surveys, which record the earth's response to numerous natural and manmade signals, can be used to assess these fundamental features Akintayo [4,5]. The oldest branch of geophysics is the study of the earth's magnetism. The earth's behavior as a massive and somewhat uneven magnet has been understood for more than three centuries.

The ground magnetic study, on the other hand, is utilized for detailed mapping to comprehend an area's subsurface geology. Measurements of the amplitude of magnetic components at discrete places along traverses spread periodically over the survey area of interest are required for this technique. Three components are measured in an in-ground magnetic study: horizontal, vertical, and total components. In previous research, the vertical components and total components were primarily employed to delineate faults, fractures, magnetic basement depth, and other geological structures. Because of their high magnetic susceptibility, the magnetic technique is ideal for identifying buried magnetite ore deposits [6]. In mineral exploration and geotechnical operations, magnetic geophysical techniques offer a wide range of uses. These methods are noted for being quick, high-resolution, non-invasive, and cost-effective. Recent advancements in electronics and medicine have raised the demand for Tantalite, which is used in the manufacture of capacitors, resistors, and implants, including dentistry and surgical equipment. Other similar research projects in Nigeria that used the magnetic survey method with the help of a proton precession magnetometer include Determination of location and depth of mineral rocks at Olode village in Ibadan Akintayo [1], Ground magnetic survey for the investigation of mineral deposits at Itesi village in Orile Ilugun [7]. Ijebu Jesa area [8], all in the southern section of Nigeria, ground magnetic data interpretation. Magnetic techniques were employed in the research to determine the location and depth of tantalite formation in the research area.

Magnetic and resistivity geophysical techniques have found a wide range of applications in mineral exploration and geotechnical work [3-5,9-13]. The electrical characteristics of the earth's materials are investigated using geophysical methods' electrical/electrical resistivity techniques, which allow for a detailed study of horizontal and vertical

discontinuities in the ground's electrical behaviors, as well as the detection of three-dimensional bodies of anomalous electrical conductivity. It is characteristically used in engineering and hydrogeological investigations to investigate shallow subsurface geology. The resistivity method provides a quantitative measure of the conducting properties of the subsurface. This method may be used to identify the depths of strata in the ground with unusually high or low conductivities, as well as the depth and approximate shape of ore bodies with unusual resistivity. The electrical Resistivity techniques give information about the subsurface distribution of electrical conductivity, and it's obtained by examining how currents flow in the earth [14]. This approach may be used to find the depths of strata with exceptionally high or low conductivities in the earth, as well as the depth and approximate shape of ore deposits with extraordinary resistivity.

The research carried out in this project is aimed at (i) Delineating possible structures that may favor the accumulation of tantalite, a magnetic mineral, (ii) Locating the position and approximating the depth of burial of these ore minerals using the magnetics method. (iii) Estimating the tantalite's depth in the study area using the Electrical resistivity method. (iv) Delineating the geophysical characteristics of the study area, (v) Determining the number of geoelectric layers in the research area.

2. LOCATION OF THE STUDY AREA

Sepeteri hamlet is located in Saki East Local Government Area, Oke Ogun, Ogun State, Nigeria. In the Oke-Ogun area of the Oyo North Senatorial district of Nigeria's state of Oyo, Sepeteri is situated between Shaki and Igboho. According to the 2006 census, Oke Ogun (Latitude 8° 00'00"N 8° 39'00" N and Longitude 2° 56'00"E 3° 46'00"E) is a populated location in Oyo State with a population of 1.4 million. It stands at a height of 188 meters above sea level [15]. The people who live in the mining districts are mostly artisan miners and farmers. This study includes a location map as well as drainage maps. There is mineral availability in the area, such as tantalite, columbite, cassiterite, kaolin, and granite.

2.1 Physiography, Drainage and Climate

The state's geography is mild undulating lowland in the south, rising to a plateau 40 meters and higher in the north. The climate is equatorial, with dry and wet seasons as well as a high humidity level. The dry season runs from November to March, and the wet season is from April to October. Almost all of the year, the average daily temperature is between 25 °C (77.0 °F) and 35 °C (95.0 °F).

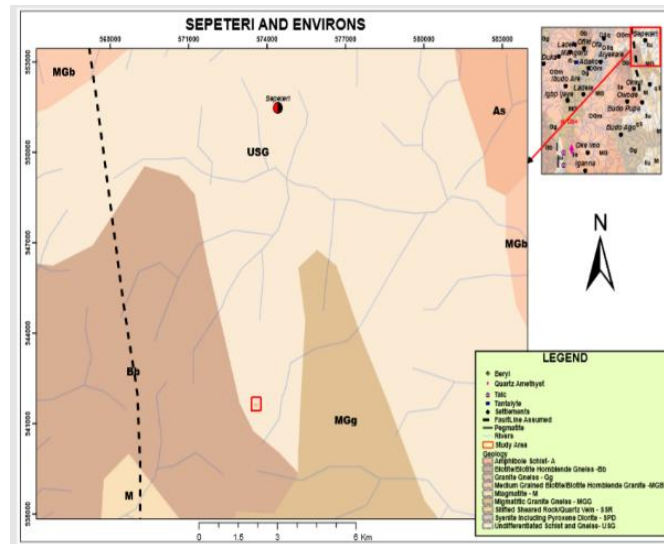


Fig. 1. Location of the study area

2.2 Geology of the Research Area

This site is covered by mica schists, weathered basement rock of lateritic (red soil) colorations with pegmatite veins, and undifferentiated meta-sediments. Rocks in this area of study have been deeply weathered leaving the surface covered with soil with a pegmatite vein trending North-East and South-West direction. The weathered lateritic red soil is a result of oxidization of the associated iron minerals, iron mineral is associated with the tantalite which is hosted by the pegmatite vein. The survey area has no physical outcrop on its surface, few pieces of rocks were found, which include: Mica Schist, Pegmatite which will be further discussed.

Mica Schist: This rock type is very dominant in the survey area and is plate-like. The rock is metamorphic and was formed about a 275million years ago during the Pangaea creation. The rock contains light and dark bands that are shiny. Mica schist is used for several decorations and as paint fillers.

Pegmatite: The pegmatite rocks were mainly found in veins that were concentrated in the map around the southwest and these rocks were formed during the concluding stages of magma crystallization. Characterized by extremely large crystals, these rocks most often contain minerals of economic importance and they contain the mineral of interest, Tantalite.

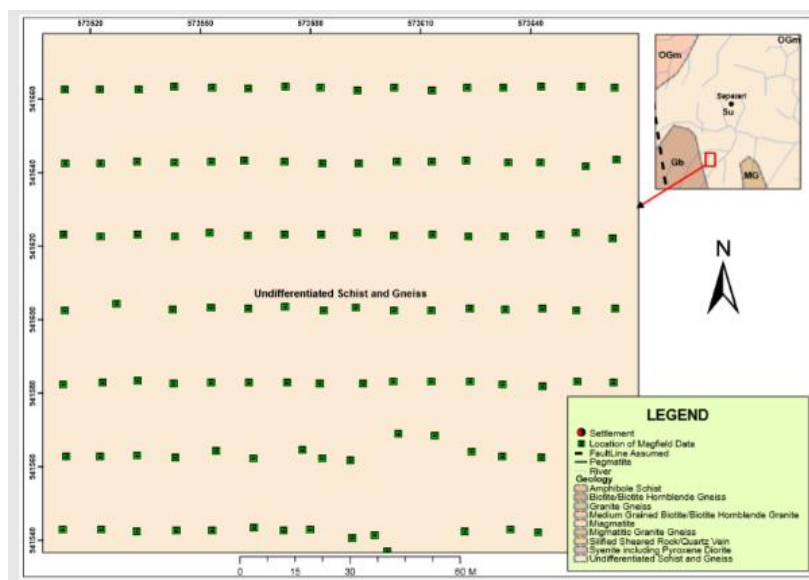


Fig. 2. Geological map of the study area

3. MATERIALS AND METHODS

3.1 Magnetic Method

The studies began with a site assessment; we avoided high-tension transmission lines as well as grounded metallic structures such as metal fences, pipes, and other sources of data noise. The magnetic measurements were made with a G-856AX proton precession magnetometer in eight (8) profiles with a 20m separation between each profile and a 10m station interval. Several impediments, such as pits bored by artisan miners, prohibited us from taking measurements at some data points in profile 5. A total of 18 data points in profile 5 were measured. In total, 158 data points were collected from the research region. The GPS was utilized to record the coordinates of each station point, as well as to draw a straight line on each profile. To remove the diurnal variable effects of the earth's magnetic field from the data, a separate magnetically clean base station was set up roughly 50 meters distant from the survey area, where magnetic readings were obtained at 60 minute time intervals. During the investigation, a grid-based survey design was used.

3.2 Electrical Resistivity Method

Resistivity data were acquired using the Herojat terrameter; the choice of this equipment was based on the fact that it can transmit signals to a very deep

depth of the subsurface. Schlumberger configuration was used and a total of six (6) Schlumberger vertical soundings (VES) were carried out in the research area. All Schlumberger soundings were 100m long. The apparent resistivity data was interpreted using partial and complete curve matching, and sounding curves were constructed [1].

4. RESULTS AND INTERPRETATION

4.1 Magnetic Method

There are different methods of interpreting magnetic data [1]. In this project research, several filtering and derivative-based techniques were done to enhance corresponding results. The matched filtering and derivative-based techniques results can be quite uncertain, and it is, therefore, important to apply different filters, each of which leverages a slightly different aspect of the magnetic anomaly data, and see whether the results are in agreement or whether they are contradictory [15]. The magnetic anomalies are usually asymmetrically positioned over their causative sources due to low magnetic inclination effects at mid-latitudes [16,17,18]. The results of the magnetic data in this study area after several filtering and derivative-based techniques have been done produce the magnetic intensity map which shows some physical meaning in terms of the subsurface geology, and are discussed below.

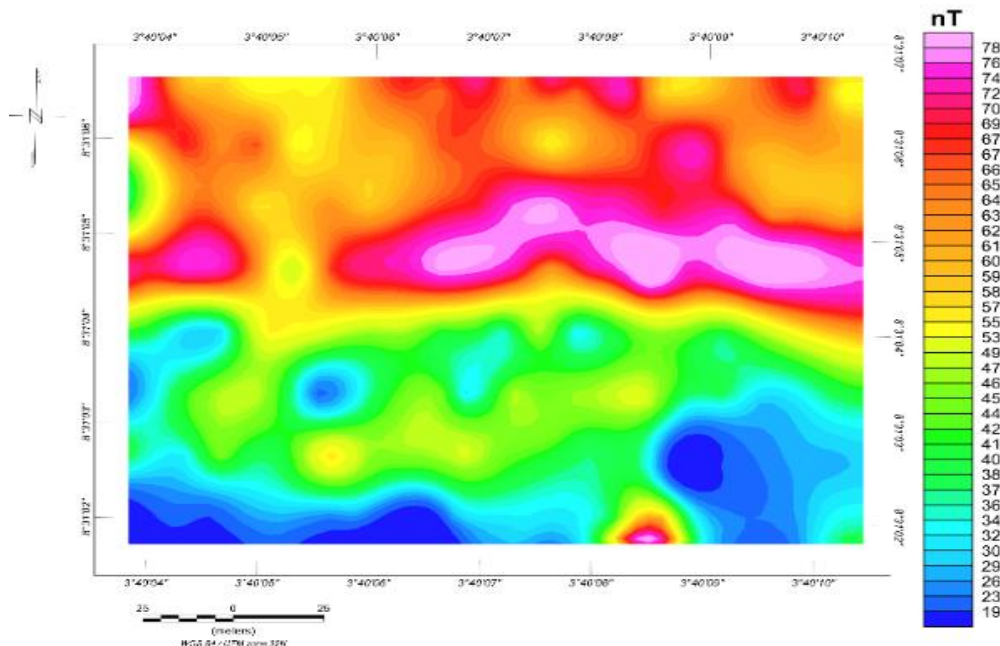


Fig. 3. Total magnetic intensity anomaly map

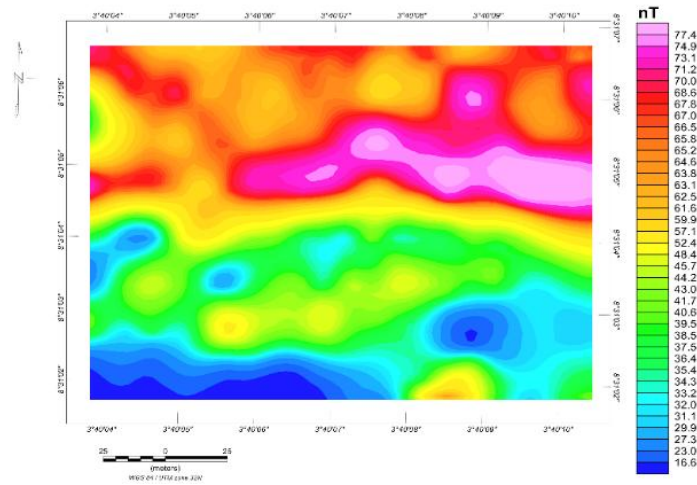


Fig. 4. Reduce-to-equator total magnetic intensity anomaly map of the study area

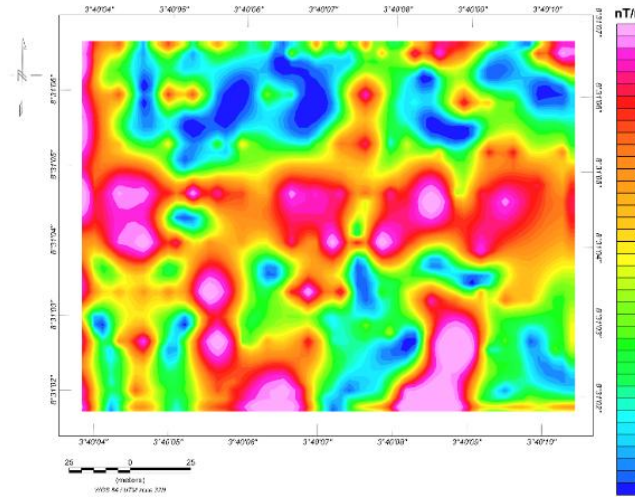


Fig. 5. Total gradient intensity map of the study area

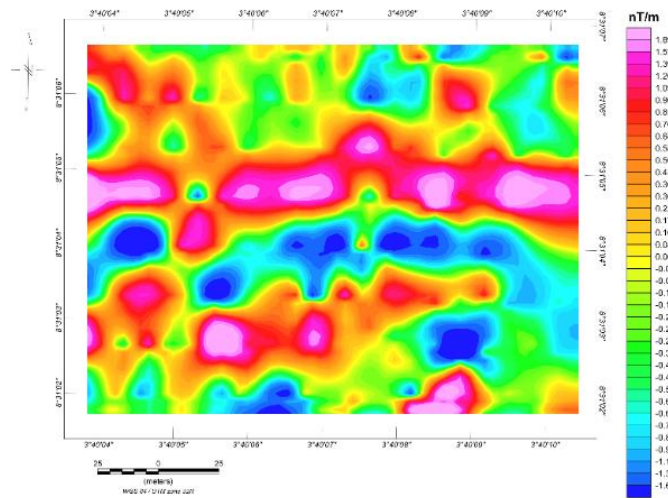


Fig. 6. First vertical derivative intensity anomaly map of the survey area

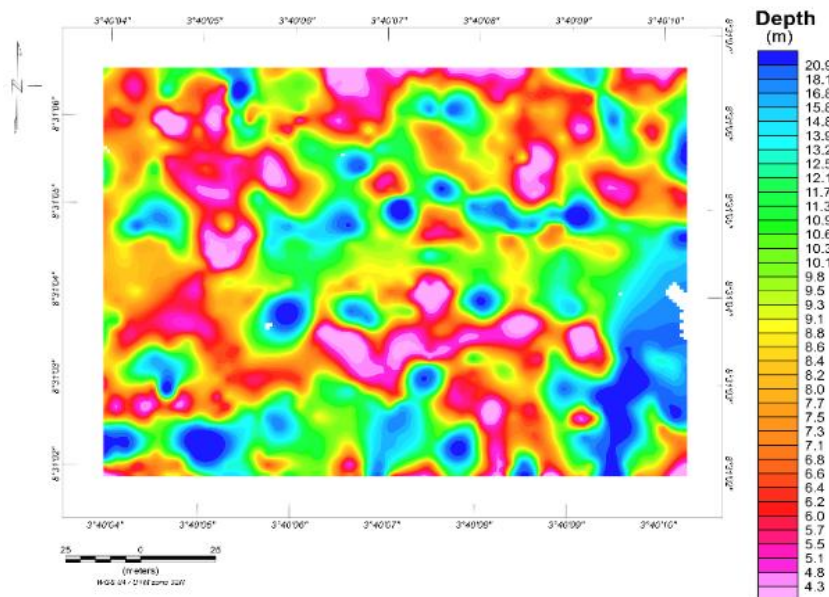


Fig. 7. Source parameter imaging depth intensity map of the study area

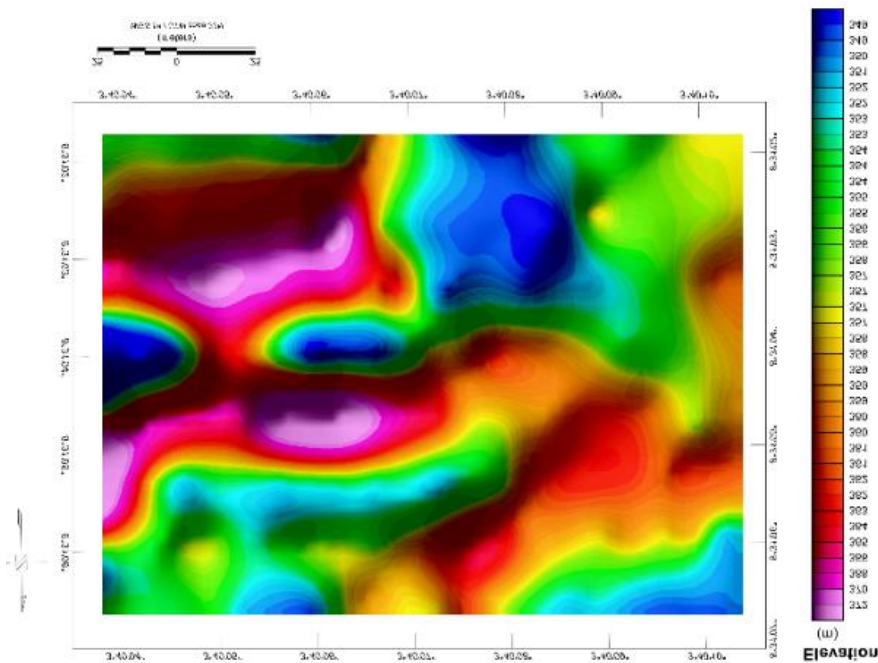


Fig 8. Elevation intensity map of the study area

4.2 Electrical Resistivity Method

The electrical resistivity data were interpreted by plotting apparent resistivity in ohm.m against electrode spacing ($AB/2$) in meters on the log-log paper and comparing the graphs with master curves types and their auxiliaries. This is a graphical interpretation technique that involves a partial curve-matching procedure, which requires the use of one or more sets of auxiliary curves in conjunction with

available two and three-layer master curves, the use of IP2WIN software was also used to interpret the electrical resistivity data by plotting the apparent resistivity in ohm.m against electrode spacing ($AB/2$) in meters, the IP2WIN software has the algorithm for inversion and iteration of electrical resistivity data for curve-matching according to [19]. The curved matched data are used to generate sounding curves according to [1]. Below are the sounding curves produced for interpretation in this research project.

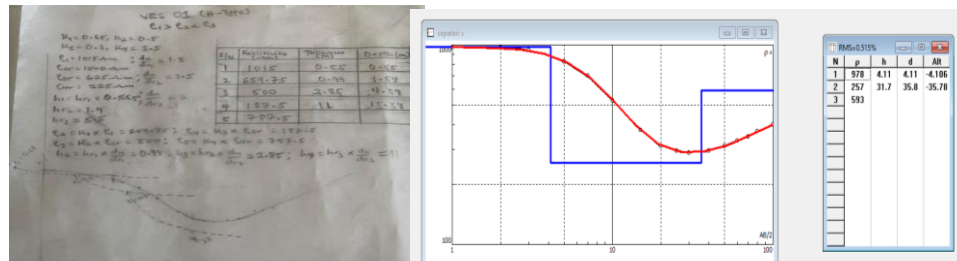


Fig. 9. Sounding curve of VES 01

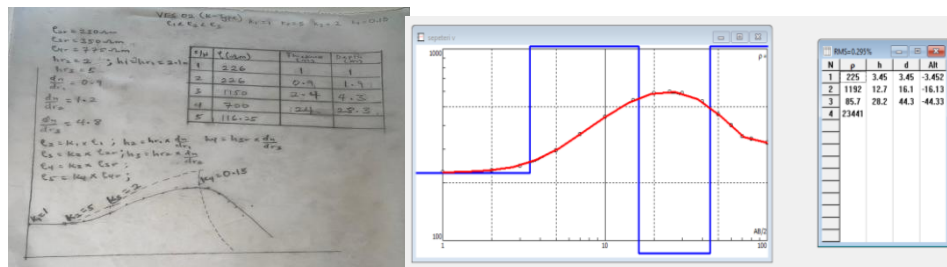


Fig. 10 Sounding curve of VES 02

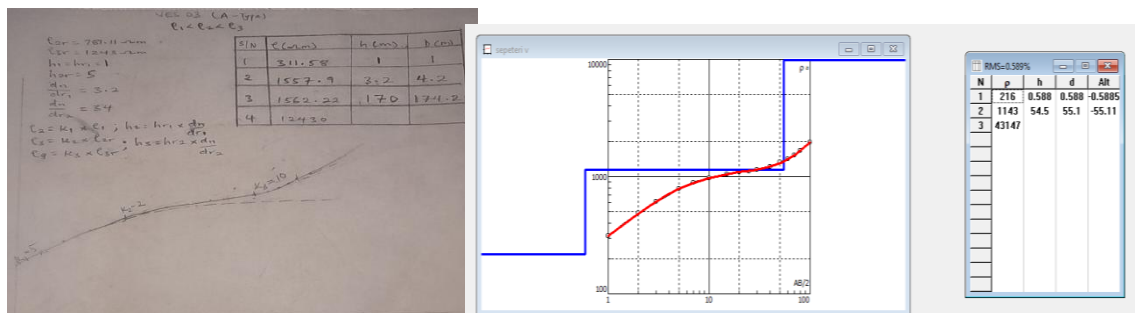


Fig. 11. Sounding curve of VES 03

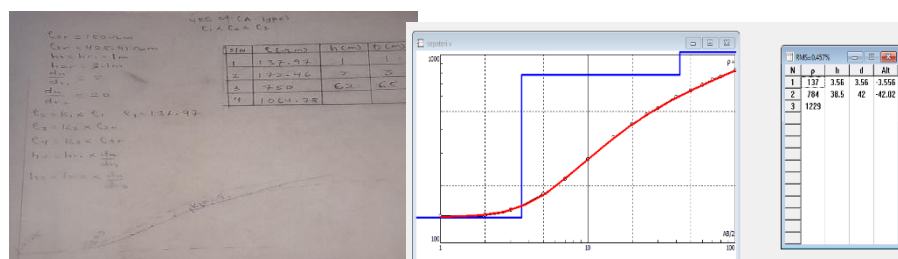


Fig. 12. Sounding curve of VES 04

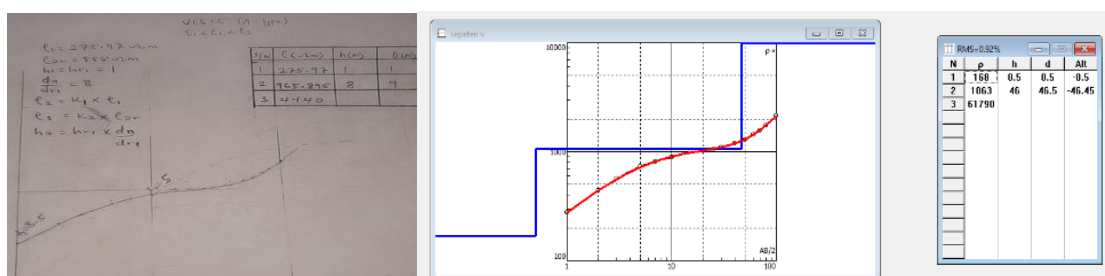


Fig. 13. Sounding curve of VES 05

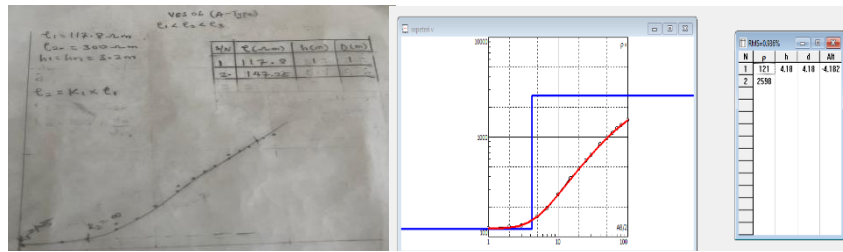


Fig. 14. Sounding curve of VES 06

5. INTERPRETATION

5.1 Magnetic Method

The magnetic intensity anomaly map of the study area Fig. 3 depicts magnetic anomaly values between 19nT to 78nT. It reveals the crustal magnetic field intensity of the area of survey and shows the area of low and high magnetic susceptibilities. Due to the survey area's proximity to the magnetic equator, magnetic source bodies are more likely to have low negative anomalies than high positive anomalies Naheem [15]. The magnetic intensity anomaly map displays substantial low-amplitude anomalies in both elongated and circular forms dispersed throughout the map's southeastern, southwestern (extremely dominant), and northwestern (very sparse) regions. The low-amplitude anomalies (which are in blue to green coloration) have high magnetic susceptibility, the medium-amplitude anomalies (which are in light-green to yellow coloration) have intermediate magnetic susceptibility, while the high-amplitude anomalies (which are in red to pink coloration) have low magnetic susceptibility. The possible rock type in the areas of high magnetic susceptibility is suspected to be pegmatite, a rock that consists of several minerals like tantalite (which is the mineral of exploration), the possible rock type in the areas of intermediate magnetic susceptibility is suspected to be mica schist, a rock which is very dominant in the study area, while the possible rock type in the areas of low magnetic susceptibility is suspected to be sandstone. Comparing the possible rock types in my area of study with [1], the rock types are similar.

The Reduction to the equator (RTE) magnetic intensity anomaly map Fig. 4 shows positive and negative magnetic sources of various wavelengths and amplitudes, also the RTE filter has centered these magnetic anomalies over their respective bodies according to [15]. The reduction to equator magnetic intensity anomaly map has a higher resolution than the magnetic intensity anomaly map, this is because the RTE map has been corrected for repositioning. The positive and negative magnetic sources have various wavelength and amplitudes values, which

range from 16.6nT to 77.4nT. The RTE map shows prominent low-amplitude anomalies distribution which is elongated and circular in the southwestern (very dominant) parts trending in the eastern direction, and the southeastern parts, but very scanty in the northwestern parts. The low-amplitude anomalies (which are in blue to green coloration) have high magnetic susceptibility, the medium-amplitude anomalies (which are in light-green to yellow coloration) have intermediate magnetic susceptibility, while the high-amplitude anomalies (which are in red to pink coloration) have low magnetic susceptibility. The possible rock type in the areas of high magnetic susceptibility is suspected to be pegmatite, a rock that consists of several minerals like tantalite (which is the mineral of exploration), the possible rock type in the areas of intermediate magnetic susceptibility is suspected to be mica schist, a rock which is very dominant in the study area, while the possible rock type in the areas of low magnetic susceptibility is sandstone. Comparing the possible rock types in my area of study with [1], the rock types are similar.

The first vertical derivative (FVD) magnetic intensity map (Fig. 6) is produced from the reduction to equator magnetic intensity anomaly map to provide greater resolution of structural features, it is utilized in the detection and mapping of geologic structures like faults and fractures which can be related to shallow basement structural features or mineral exploration targets, it demarcates possible edges of geologic source bodies, it also facilitates the vertical location within the study area, when utilizing the RTE transformation, the FVD is negative (which are in blue to light-green coloration) when it is over magnetic source bodies and is positive (which are in red to pink coloration) when it is outside the magnetic source bodies according to [15]. It has a range of values from -1.69nT/m to 1.89nT/m. The blue to light-green coloration in the FVD map shows the area of the geological structure which can be faults or fractures that are both elongated and circular are found in the western part trending to the eastern part (very dominant in this part), the southern part, the

southwestern part, they are scanty in the northeastern, and very scanty in the northwestern part.

The Source parameter imaging (SPI) depth intensity map (Fig. 7) is effective in low-latitude regions such as the area of study to estimate depths to the top of magnetic geological structures like dykes, faults, or fractures which can be related to shallow basement structural features or mineral exploration targets from the FVD map (Fig. 6), according to [15]. The SPI map (Fig. 5.1d) has a range of values from 4.3metres to 20.9metres, the blue to green coloration is the area that has high depth and are located both in elongated and circular shapes in every part of the study area but is very dominant in the southeastern part of the study area, the light green to yellow coloration is the area that has intermediate depth and is located in every part of the study area, but very scanty in the southeastern part, the red to pink coloration is the area that has low depth and is located both in elongated and circular shapes in every part of the study area, but not dominant in the southeastern area. The low depth areas of the SPI map are of interest because in mining the miners are interested in shallow depth of the subsurface for easy excavation. The northern, western, south-western, north-western, and central part of the study area is likely the most suitable areas to excavate.

The total gradient magnetic intensity anomaly map (Fig. 5) of the study area is used to show the magnetization contrast in the study area, it has a range of values from 0.31nT/m to 3.30nT/m. The red to pink coloration depicts the area that has high magnetic contrast and is located both in elongated and circular shapes in the western part which trends to the eastern part (very dominant in this part of the survey area), it is also located in the southeastern and southwestern part of the study area. The light-green to yellow coloration depicts the area that has medium magnetic contrast and is located in the western part which trends to the eastern part, and also in the southeastern part and southwestern part but are not dominant in these parts of the study area compared to the red to pink coloration. The blue to green coloration depicts the areas that have low magnetic contrast and are located both in elongated and circular shapes in the northern part (very dominant) part of the study area, and are also in the southern, southwestern, and southeastern part but not dominant compared to the northern part of the study area.

The elevation intensity map (Fig. 8) shows the height above sea level to the point where the observer is taking the magnetic measurement. It has a range of values from 349metres to 372metres. The elevation map of the study area is used to study how the tantalite has moved or flowed in the study area due to

weathering and erosion. The orange to pink coloration indicates the areas with high elevation, while the green to yellow coloration indicates the area with medium elevation, and the blue coloration indicates the areas with low elevation. From the elevation map, it can be seen that the coloration which depicts the high elevation is dominant in the north-western part and western part, it then moves downwards to the southwestern part where it is concentrated, this is as a result of the weathering and erosion which has washed away the rock associated with tantalite mineral from the western and northwestern area and deposit it in the southwestern part of the study area.

5.2 Electrical Resistivity Method

The apparent resistivity values in each of the sounding curves give an insight into the rock types in each layer of the vertical electrical soundings.

VES 01 (Fig. 9) gives the H type curve

VES 02 (Fig. 10) gives the K-type curve and shows that complex basements are not very close to the surface of the earth [1].

VES 03 to VES 06 (Fig. 11 to Fig. 14) give A type curve. This implies that some minerals or rocks in the study area contain magnetite ore which is a black magnetic mineral that has a large content of iron oxide, and it depicts low resistivity which is highly conductive according to [1]. Comparing the findings of [1] to the research findings:

The resistive values range from 121 Ω m to 2500 Ω m in the subsurface of the study area where the vertical electrical sounding was done. The low resistive values reveal high conductivity areas which is the zone of interest because tantalite is a conductive mineral, and it is located in the southwestern part of the study area.

These findings predict that there are some magnetic rocks or minerals in the southwestern part of the study area where the vertical electrical sounding was performed.

6. CONCLUSION

The results of the magnetic method and the electrical resistivity method used to study the subsurface features of tantalite mineralization in the Olorunda mining site, Sepeteri were in agreement and the following conclusion was made.

The high magnetic susceptibility and low resistivity values from the western, southwestern, central, and some part of the eastern area is as a result of the iron oxide associated with the tantalite mineralization

which is hosted by pegmatites vein trending NE-SW. About 50% of the rock units in the study area are dominated by mica schist which has intermediate magnetic susceptibility and electrical resistivity values, which is the most dominant. The low magnetic susceptibility and high resistivity values towards the eastern to the north-eastern part of the study area is as a result of weathered rocks or probably sandstone because part of the survey area is deeply weathered and has a thick overburden.

The SPI magnetic anomaly intensity map reveals the depth to the faults/fractures from 4.3metres to 20.9 metres.

Since the tantalite mineralization of the study area is associated with iron oxide, it is, therefore, a ferromagnetic mineral. Thus, the integration of magnetic susceptibility and electrical resistivity method proves to be the vital investigation of tantalite mineralization.

From the estimated results gotten from the interpretation of both magnetics and electrical resistivity data acquired in the study area, one can deduce that ferromagnetic minerals like tantalite which is the main target for exploration are present. So, therefore, to get a more detailed geophysical investigation within the area of study an extensive all-encompassing geological mapping/survey needs to be done because the area has little qualitative/quantitative geological information, for this reason, geological correlation of geophysical investigation is not adequate or detailed.

DECLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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