



ASSESSMENT FOR GOLD MINERALISATION POTENTIAL OVER ANKA SCHIST BELTS NW NIGERIA, USING AEROMAGNETIC DATA

*¹Augie, A. I., ²Adamu, A., ³Salako, K. A., ³Alkali, A., ²Narimi, A. M., ⁴Yahaya, M. N., and ²Sani, A. A.

^{1&2}Department of Applied Geophysics, Federal University Birnin Kebbi, Nigeria.

³Department of Geophysics, Federal University of Technology Minna, Nigeria

⁴Department of Physics with Electronic, Federal University Birnin Kebbi, Nigeria

*Corresponding authors' email: ai.augie@fubk.edu.ng +2348137330559

ABSTRACT

High resolution aeromagnetic data combined with the geological settings of the study area were employed in delineating the structures that may host the gold mineral within the middle parts of Anka schist belts. These data were analysed, processed and interpreted using; reduction to magnetic equator (RTE), first and second vertical derivatives (FVD & SVD), geologic contact, analytic signal (AS), centre for exploration targeting (CET) and source parameter imaging (SPI) techniques. RTE technique was applied to prevent North-South signal in the data from dominating the results, due to the area falls under the low latitude. FVD and SVD maps shows major NE trend of the structures within study area. CET map revealed the regions with linear structures (lineament) which were trending South-Eastern regions of the study area. Geologic contact map has highlighted high density of structural contacts combined with junctions and intersections of different structures found within the area. AS map enhanced the variation in the magnetisation of the magnetic sources and also indicates the boundaries of anomaly texture. These techniques have revealed the regions that may host gold mineralisation potential areas to be; northern parts of Bukkuyum, Anka, Maru, Sakaba, Mariga, southern part of Wasagu/Danko. Most of the structures (lineaments) found within areas were associated with the vein of the mineralisation potential which plays important role in determine a gold mineral. Results from these techniques also correlated well with the geological setting of the study area. The depth to the boundaries of these causative bodies were found to be from 90 m to 122.8 m using SPI technique.

Keywords: Gold Mineralisation, Anka-Zuru Schist belts, CET, Geologic Contact, SPI and AS.

INTRODUCTION

Naturally, gold is a relatively common mineral that usually exist in quartz veins, alteration and oxidized zones of many sulphides and hydrothermal deposits, and in streams/ or rivers in most parts of the world (Augie and Ridwan, 2021). Hydrothermal gold deposits occur in orogenic belts that range in age from Precambrian to Late Tertiary (Garba, 2000). They are commonly found associated with stocks, batholiths and other igneous intrusions of intermediate to acid composition (Garba, 2003).

The gold orebodies mainly occur in quartz veins, veinlets and tiny stringers. It's can be found associated with; phyllites, schists and quartzites (Augie and Sani, 2020). They have a sharp vein-wall rock contacts and the gold occurs in its native form as inclusions in minerals like chalcocopyrite and galena (Sani *et al.*, 2017). The veins do not always have a well-developed wall rock alteration pattern, are marked by silicification, sericitization and carbonation. At the old open-pit mines, the miners often mined the soft (altered) wall rocks which must have been gold bearing, leaving behind the main vein of a massive hard quartz body (Sani *et al.*, 2019).

The earth's magnetic field originated from the core and effectively magnetized susceptible rocks usually in the earth's crust. The processes by which this can happen are the phenomena of magnetic induction, and this play most important/accountable for the great majority of magnetic variation observed by aeromagnetic surveys (Reeves, 2005). Usually, earth's magnetic field behaves remarkably like a bar magnet located in the earth core. It is dipolar, having north

pole in the Arctic and a south pole in the Antarctic, these magnetic poles do not coincide with the geographic poles, and they are not stationary. The strength and orientation of the magnetic field vary relatively smoothly across the globe reaching minimum strength and having a horizontal orientation in equatorial regions (Isles and Rankin, 2013). The magnetic field definitions of north, south, upward and downward are scientific conventions; the key point for the aeromagnetic interpreter is that magnetic anomalies due to rock bodies which vary according to their location on the globe because the earth's field is the principal cause of magnetization in the crust (Augie and Ologe, 2020).

Bonde *et al.* (2019) used aeromagnetic data for structural mapping associated with solid mineral potential zones in some part of Anka schist belt. Similarly, Sani *et al.* (2019) adopted the same method for the analysis of gold mineral potentials in Anka schist belt. Study area falls under the low latitude area and none of the Authors applied reduction to equation technique. However, at low latitudes, a separate amplitude needs to be corrected to prevent North-South signal in the data from having abnormal noise in the results according to Authors; Holden *et al.* (2008), Core *et al.* (2009) and Augie *et al.* (2022).

This study used aeromagnetic data with the view to delineating gold bearing alteration zones in the study area. This was achieved by employing reduction to magnetic equator (RTE), first and second vertical derivatives (FVD & SVD), geologic contact, analytic signal (AS), centre for exploration targeting (CET) and source parameter imaging

(SPI) techniques. These techniques revealed the depth and major structural trends that control gold mineralisation within the Anka to Zuru schist belts.

METHODOLOGY

Location and Geological Setting of the Study Area

The study area lies between latitudes 11°0'0"N and 12°0'0"N, and longitudes 5°30'0"E and 6°0'0"E. These covers the following areas; southern part of Bukkuyum, Anka, Maru, Wasagu/Danko, northern part of Sakaba and Mariga (see Figure 1.).

Geologically, the area falls under Anka-Zuru schist belts. The southern part of Bukkuyum, Anka and Maru are underlain by; quartz, mica schist, diorite, migmatite, biotite-homblende,

granite, medium coarse grained, sandstones, ironstones and laterites. Similarly, Wasagu/Danko comprises of; biotite gneiss, quartz, mica schist, diorite, migmatite, biotite-homblende, granite and medium coarse grained. The northern part of Sakaba and Mariga are underlain by; diorite, migmatite, biotite-homblende, granite, medium coarse grained and biotite gneiss (see Fig 2.). Furthermore, Danbatta (2008) discussed that the dacites/rhyolites are overlain and intrude the basement gneisses, metasediments and granitic rocks of the Anka-Yauri schist part Kebbi. A brittle fault zone cuts the area consisting of sub-parallel phyllites and crushed and uncrushed quartzites, and forms part of the mapped Anka transcurrent fault which is interpreted as a possible Pan-African crustal suture (Danbatta 2005).

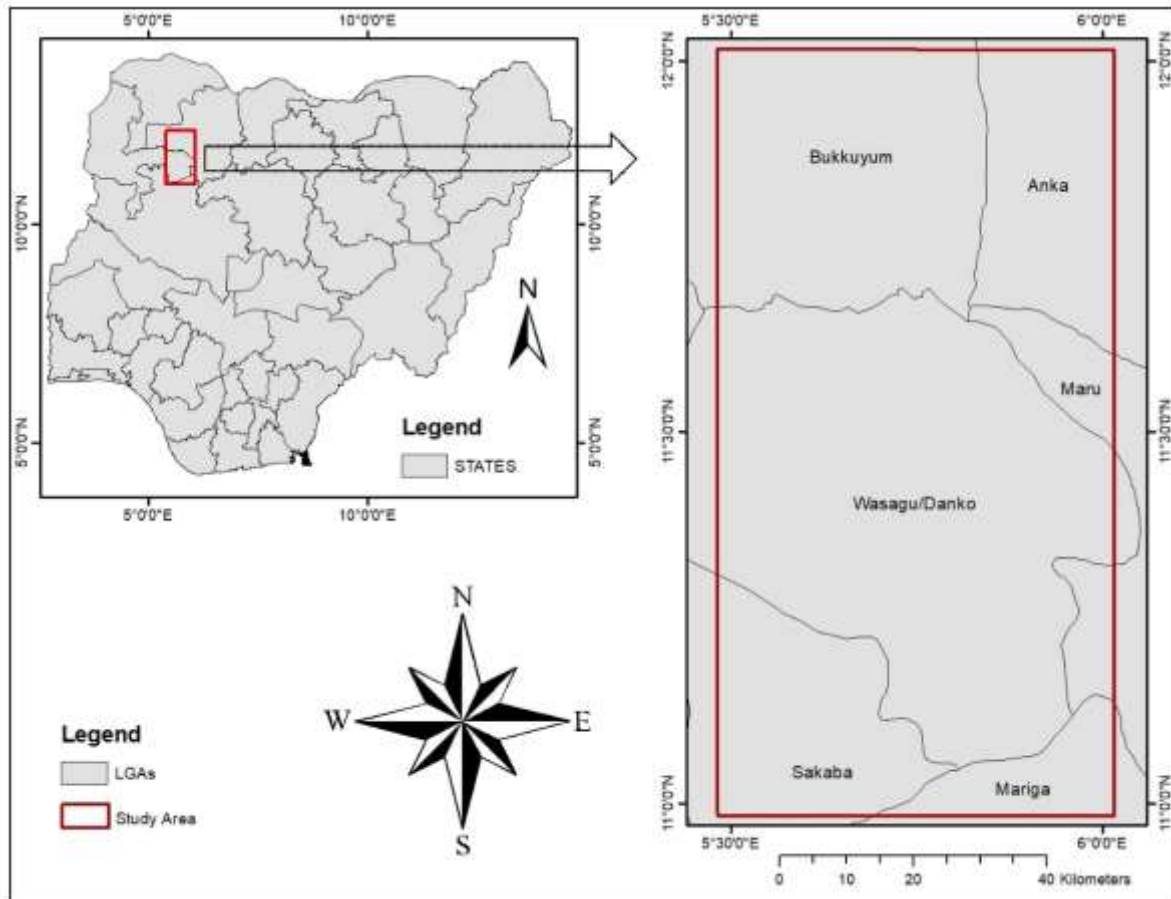


Figure 1: Location of the Study Area

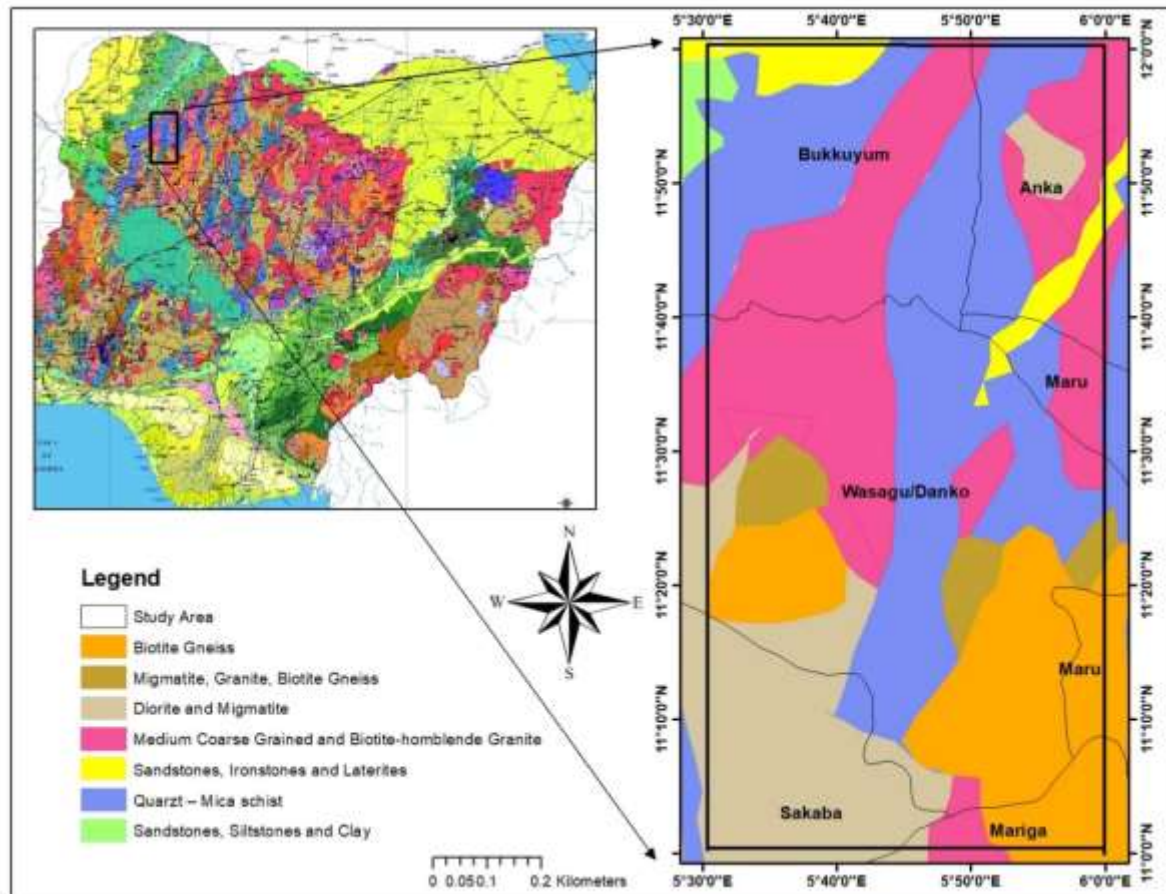


Figure 2: Geological Setting of the Study Area (Olugbenga and Augie, 2020).

Data Acquisition

This study used aeromagnetic data acquired from Nigeria Geological Survey Agency (NGSA). The surveys were carried out by Fugro airborne between 2005 and 2010 sponsored by Federal Government of Nigeria. The acquired data were then handed to NGSA. Two (2) aeromagnetic data sheets were used in this study and the data have covered; Bukkuyum, Anka, Maru, Wasagu/Danko, northern part of Sakaba and Mariga, of Kebbi and Zamfara states. These aeromagnetic data sheets are; Gwashi-75 and Wasagu-98.

The datasets were acquired under the following high-resolution survey conditions; Flight line spacing (500 m), Terrain clearance (80 m), Tie line spacing (2000 m), Flight direction is NW-SE and the Tie line direction is NE-SW. The magnetic datasets were recorded by the instruments called 3×3 Scintrex CS3 cesium vapour magnetometer sensor which was attached on a fixed wing of the aircraft.

This method measures basically admixture of the earth's core field and the field due to magnetized susceptible rocks in the earth's crust combine with the remanence field of the rocks (Augie et al., 2022). For this, these data were further corrected by removing geomagnetic gradient using the International Geomagnetic Reference Field (IGRF). Acquired grid data were assembled and merged in order to have the composite map of the study area. These were further converted in digitized form of; X (longitude measured in metre), Y (latitude measured in metre) and Z (magnetic intensity measured in nano Tesla). The corrected aeromagnetic dataset was subjected to the minimum curvature gridding method to produce the Total Magnetic Intensity (TMI) map of the study area (Figure 3A).

DATA PROCESSING

Processing techniques like reduction of magnetic equator (RTE), first and second vertical derivative (FVD & SVD), geologic contact, centre for exploration target (CET), analytic signal (AS) and source parameter imaging (SPI) were used to process this data with aid of Geosoft (Oasis Montaj) and Surfer software.

The TMI value acquired from NGSA was short-up by 33,000 nT for the convenience of contouring or imaging, the value (33,000 nT) was added back to give the TMI grids for the area. The generated core fields (IGRF for the epoch period) are subtracted from the grid values of TMI so as to give the magnetic anomaly as shown in Figure 3A.

Reduction to Magnetic Equator (RTE)

The study area falls within magnetic equatorial zones of low latitudes/inclination. In this area, the North to South bodies have undetectable induced magnetic anomaly at zero geomagnetic inclination. Consequently, the TMI map (Figure 3A) were subjected to magnetic equator to produce anomalies of magnetized body that usually depend on the inclination, declination, local earth's field and orientation of the body with respect to the magnetic north.

The resultant composite map of the reduced-to-equator residual magnetic anomalies are given in Figure 3B. The map indicates different magnetization within the study area and these magnetic anomalies of the earth's materials measure magnetic susceptibility. Regions with high magnetic zones were correspond to; NW part of Bukkuyum, central part of Anka, Maru, southern part of Wasagu/Danko and Sakaba. The zones with low magnetic signatures are; SE part of Bukkuyum, Northern part of Anka, Northern part of Wasagu/Danko and Mariga.

High and low magnetic zones were characterized by difference in rock formations and these lead to difference in the magnetic susceptibility of the rocks within the area (see

Figure 3B). Susceptible rocks usually occur at depths shallower than the curie points isotherm.

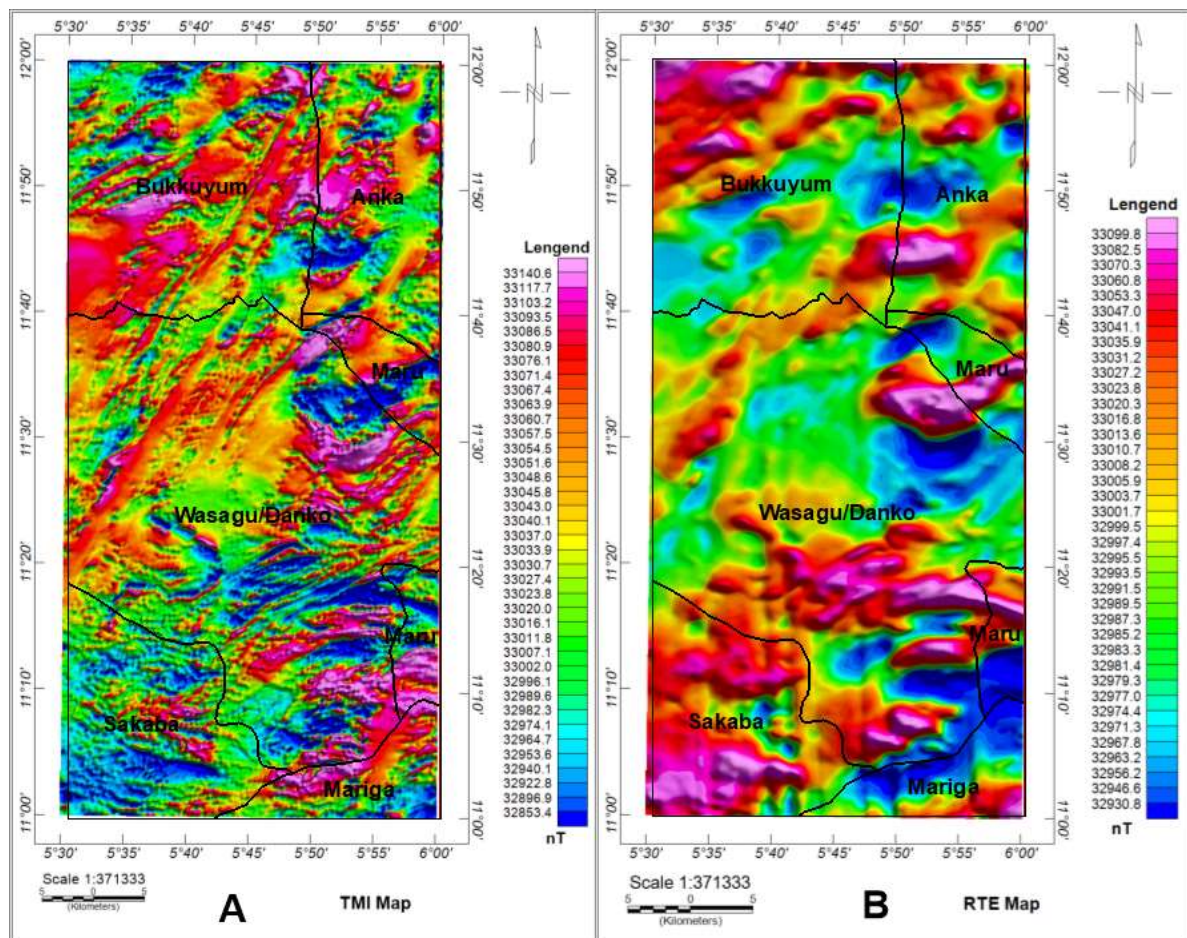


Figure 3: (A) Total Magnetic Intensity and (B) Reduction to Equator Maps of the Study Area

First and Second Vertical Derivatives (FVD & SVD)

FVD and SVD techniques were applied to TMI anomaly (RTE) in order to quantify the spatial rate of changes of the magnetic field in horizontal, or vertical directions. These techniques are usually essential in enhancing the shallow features (high frequency anomalies) as compare to deep features (low frequencies anomalies) and also used to sharpen the edges of anomalies. Observing Figure 4A closely, most of the structures delineated are found within northern parts of Bukkuyum, Anka, Maru, Sakaba and Mariga, and southern part of Wasagu/Danko areas.

SVD map (Figure 4B) is more effective and resolving power than FVD map and it provided much more detailed structures and also enhances the high frequency anomalies as measured in RTE map. Figure 4B has intensified the major delicate anomalies thereby enhanced the boundaries of anomaly in near surface which effects the characterized edges of the causative bodies. These structures found in FVD and SVD maps are the architecture of a mineralized body associated with gold mineral and these zones were corresponded to the aforementioned areas.

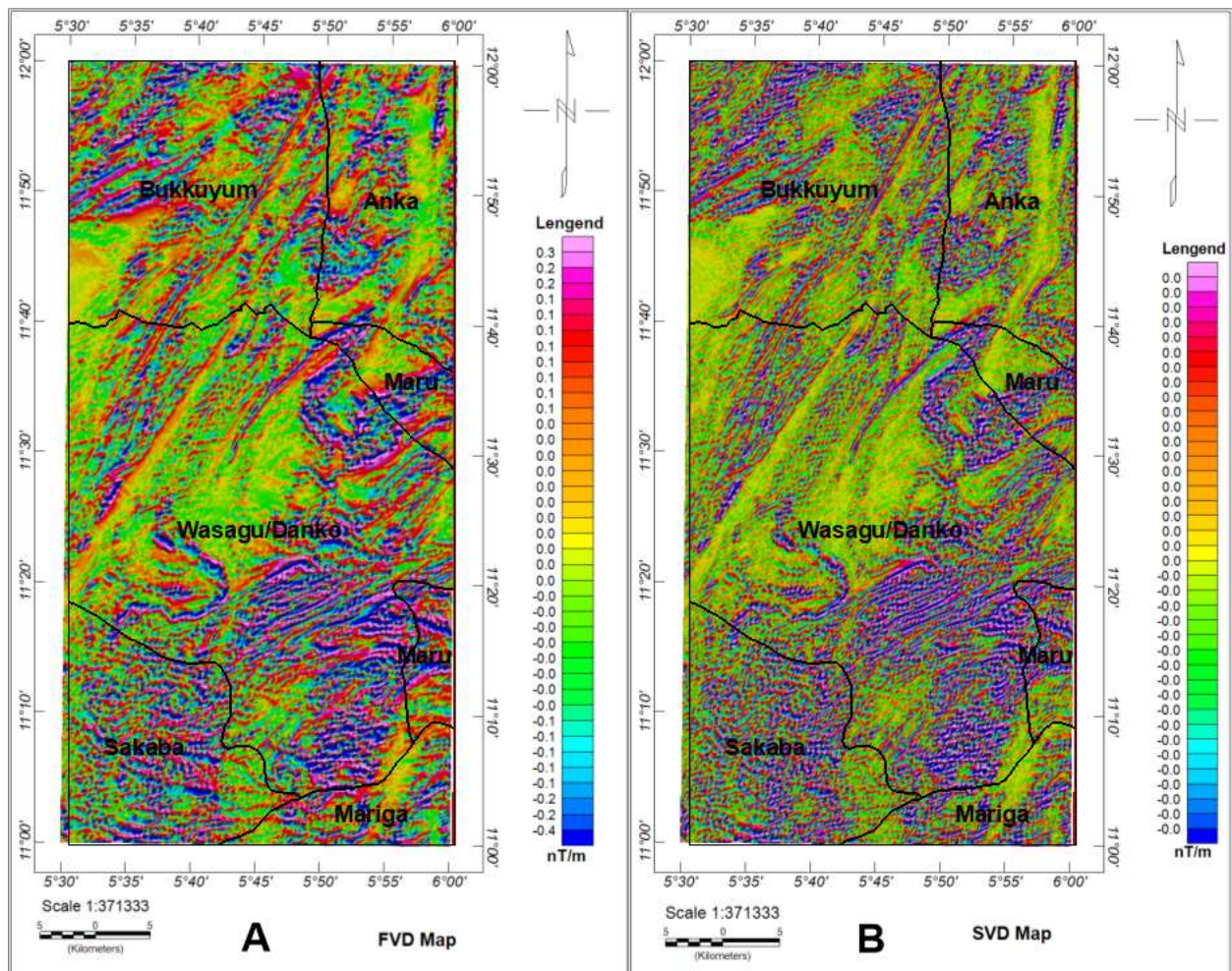


Figure 4: (A) FVD and (B) SVD Maps of the Study Area

Centre for Exploration Target (CET) And Geologic Contact

CET and Geologic contact techniques were also applied to RTE grid data anomaly for structural features (fractures, faults/ or shears zones), delineating the boundaries within schist belts, and detect the position of the outcrops and intrusive bodies in the area.

Figure 5A reveal the regions with lineament and these zones were trending to South-East of the study area. The zones with linear structures have falls under the following areas; northern parts of Bukkuyum, Anka, Maru, Sakaba and Mariga, and southern part of Wasagu/Danko. These structures were also falls within the basement complex in area underlain by the following earth materials; quartz, mica schist, diorite, migmatite, biotite-homblende, granite, medium coarse grained, sandstones, ironstones and laterites as compared with the geological setting of the area. These zones have also correlated well with structures found in FVD and SVD maps of the area. Most of linear structure found within these areas, are trending in the NE directions. Regions having these shears zones (lineaments) were represent as vein of mineralization as compared with the geology of the area (Figure 2). The rocks forming in the area usually play an important role in gold mineralization exploration since most gold deposits in Nigeria are found in quartz veins.

Figure 5B, has generates a heat map called geologic contact map that highlights high density of structural contacts combined with junctions and intersections of different structures and locations where structures have significant orientation changes. These zones were located at; northern parts of Bukkuyum, Anka, Maru, Sakaba, Mariga, and southern part of Wasagu/Danko, and these regions were well agreed with the results found in CET, FVD and SVD maps.

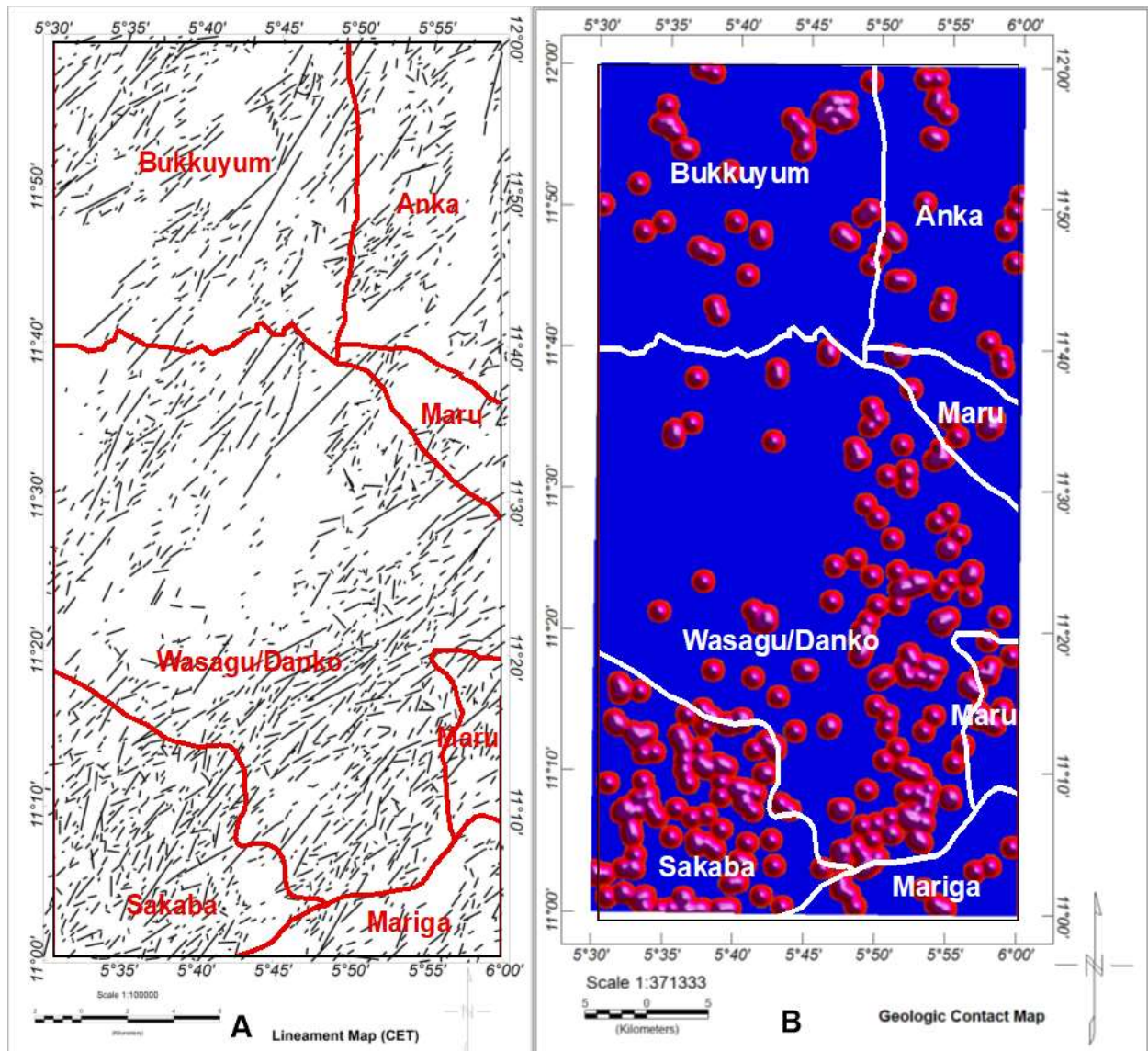


Figure 5: (A) Lineament (CET) and (B) Geologic Contact Maps of the Study Area

Analytic Signal (AS) and Source Parameter Imaging (SPI)

The analytic signal technique was applied to RTE grid map to estimate source characteristics of earth materials and also delineate the positions of causative body (Figure 6A). The technique was applied to detect the direction of magnetization, enhanced the variation in the magnetization of the magnetic sources and also indicates the boundaries of anomaly texture.

Observing Figure 6A closely, three different magnetic zones were delineated which are; low (0.0 nT/m to 0.1 nT/m), moderate (0.1 nT/m to 0.2 nT/m) and high (above 0.2 nT/m) magnetic signatures. Low magnetic regions (low amplitudes) were named as Zone B and these areas were associated with sandstones, siltstones, clays shale's, limestone and laterites as compared with geological setting of the area (Figure 2). Similarly, high magnetic areas (high amplitudes) were associated with biotite gneiss, quartz, mica schist, diorite, migmatite, biotite-homblende, granite and medium coarse grained. The zones with high amplitude over the edge of the magnetic structures named as Zone A due to magnetic anomalies around the regions which is associated with ferromagnetic Fe bearing rock. These regions were also falls on northern parts of Bukkuyum, Anka, Maru, Sakaba, Mariga, and southern part of Wasagu/Danko

SPI map (Figure 6B) specified the depth of these boundaries of causative bodies found in FVD, SVD, CET and AS maps. This technique categorized the depth of the study area into four which are; 90 m to 122.8 m, 122.9 m to 174 m, 174.9 m to 242.9 m and 243 m to 463.5 m respectively. The zones of 140 m to 174 m and 174.9 m to 242.9 m depth were correspond to the regions of faults/structural trends identified in northern parts of Bukkuyum, Anka, Maru, Sakaba, Mariga, and southern part of Wasagu/Danko of the study area.

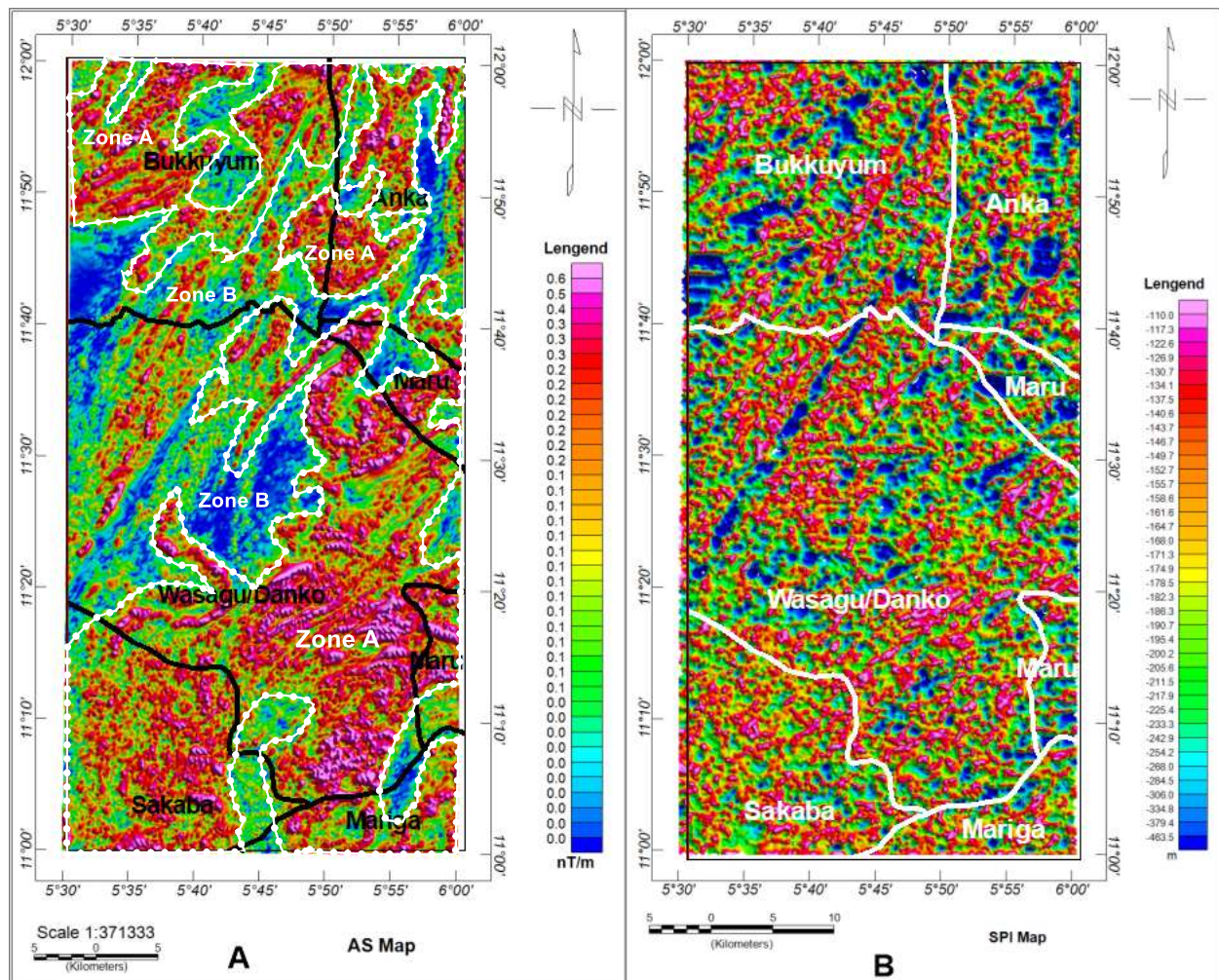


Figure 6: (A) Analytic Signal (AS) and (B) Source Parameter Imaging (SPI) Maps of the Study Area

RESULTS AND DISCUSSION

RTE, FVD, SVD, CET, Geologic contact, and SPI processing techniques shows that the regions were made of different magnetic zones and also exhibit substantial positive magnetic susceptibility values that are more of ferromagnetic minerals such as gold mineralization potential. The structures found in FVD, SVD and CET maps play important role in delineation of gold mineralization within the study area.

The results found from aforementioned techniques have delineated the possible pathways for gold exploration and exploitation as describes in northern parts of Bukkuyum, Anka, Maru, Sakaba, Mariga, and southern part of Wasagu/Danko areas. These regions were occupied with quartz, mica schist, diorite, migmatite, biotite-hornblende, granite, medium coarse grained, biotite gneiss and migmatite as compared with the geological setting of the area. The estimated depth to the magnetic sources found within the regions was found to be from 90 m to 122.8 m (Figure 6B). The aforementioned rocks type found within the regions usually contained Fe-bearing minerals (gold mineral) and the distribution of the crystallized gold species indicated in these areas increasingly with oxidized of Fe-bearing minerals from mafic to felsic rocks.

There are also regions of sedimentary rocks as observed (Figure 6B) called Zone B. These regions coincide with the following rocks formation; sandstones, ironstones and laterites. These zones are strongly controlled by carbonates content and species that usually dependent on both

sedimentary facies and sediment provenance, and the area corresponded to northern part of Wasagu/Danko.

CONCLUSION

The result from this geophysical study has revealed the regions that might host the gold mineralization as shown in Figures 3 to 6 and these regions were corresponded to the following local government areas; in northern parts of Bukkuyum, Anka, Maru, Sakaba and Mariga, and the southern part of Wasagu/Danko. The study revealed the structures (faults, fractures/ or shears zones) associated the vein of mineralisation with the area. These structures play an important role in determine gold and other minerals. SPI depth map specified the depth of the boundaries of causative bodies with the aforementioned area, and its was found to be from 90 m to 122.8 m.

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