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ANALYSIS OF GOLD MINERAL POTENTIALS IN ANKA SCHIST BELT, NORTH WESTERN NIGERIA USING AEROMAGNETIC DATA INTERPRETATION

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Abstract

Gold is an important resource located within the subsurface, and its mineralization is Vcontrolled by geology, structures and hydrothermal alteration within rock formations. The search for gold is therefore the search for structures within hydrothermally altered zones in the subsurface. For this reason, aeromagnetic data are used to interpret the geology and geological structural patterns which serve as potential gold mineralization zones in the Anka area located at North-western Nigeria. Aeromagnetic data of Anka schist belt lies between the latitude 12°00ʹE to 12° 30ʹN and longitude 5° 30ʹE to 6°00ʹE between the boundary of basement complex rocks and sedimentary rocks of the Sokoto Basin Trough flown at an altitude of 80m with line spacing of 500m and cross tie of 2km was used for this study. The data was made available in the digital form on the scale of 1: 50, 000. The data was further processed, enhanced and interpreted with Geosoft (Oasis Montaj), on a Geosoft platform the datasets were projected to Universal Transverse Mercator (UTM) coordinate system Zone 32N using World Geodetic System (WGS) 84 as the datum. The data was then gridded with the minimum curvature method of gridding. The application of the enhancement filtering algorithms such as the reduction to the pole and analytic signal to the magnetic data, aided in the mapping of the metasediments MS (quartzite, phyllite and metaconglomerate), basin granitoid BG (fine and coarse grain granite) and gudumi formation GF (sandstone and alluvial). The first vertical derivative and second vertical derivative filters helped to delineate fractures, folds, and the contact zones of the formations. Four mapped zones were identified with subsurface structures namely zone A (lat. 12° to 12°10ʹN and long. 5°30ʹ to 5°35ʹE)., zone B (lat. 12° to 12°10ʹN and long. 5°40ʹto 6°E)., zone C (lat. 12°10ʹ to 12°20ʹNand long. 5°40ʹto 5°50ʹE). and zone D (lat. 12°25ʹ to 12°30ʹNand long. 5°55ʹto 6° 00ʹE). Respectively. These zones are major fracture systems and play a pivotal role in the localization of gold mineralization in the study area.

Keywords*: Aeromagnetic data, Schist belt, Lineaments*

1. INTRODUCTION

Orogenic gold deposits are present in metamorphic terrains of various ages, displaying variable degrees of deformation [1]. They are structurally controlled and spatially associated with shear zones and hydrothermal veins formed in response to the regional stress field. Faults and shear zones are potential pathways of fluids [2]. and the, knowledge of the structural architecture of a mineralized area, the distribution and orientation of faults and shear zones, their formation and possible reactivation during the structural evolution and the tectonic conditions is a key to understanding the formation, origin and location of mineral deposits as well as for exploration and findings of new targets [3].Magnetic survey is a well-known technique to delineate subsurface structures and has been extensively used in many parts of the world. Magnetic susceptibility is the significant variable in magnetic survey. the magnetic anomalies are caused by magnetic minerals (mainly magnetite and pyrrhotite) contained in rocks[4]. Most rock forming minerals are magnetized by induction in the Earth's field, and cause spatial perturbations or "anomalies" in the Earth's main field. The man-made objects such as iron or steel are highly

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magnetized and locally will cause compromised magnetic anomalies up to several thousands of Nano Tesla (nT)[5]. Aeromagnetic surveys are widely used to aid in the production of geological maps and also commonly used during mineral exploration. Some mineral deposits are associated with an increase in the abundance of magnetic minerals (e.g. iron ore deposits), but often the elucidation of surface structure of the upper crust is the valuable contribution of the aeromagnetic data [6].

1.1 Location and Geology of the Study Area

The study area is located in Zamfara state, between the latitude 12^{o}N to $12^{o}30^{'}$N and longitude 5^{o} $30^{'}$E to $6^{o}00^{'}$E north western Nigeria between the boundary of basement complex rocks and sedimentary rocks of the Sokoto Basin (Fig 1). Igneous, metamorphic and sedimentary rocks outcrop within the study area. Meta sediments within the study area are believed to be relics of an older super crustal and compose of phyllites, meta-conglomerates and quartzites. Granites within the study area are syntectonic to late tectonic inclusions emplaced into both migmatites gneiss and super crustal rocks during just and after the main Pan African deformation[7]. Granites consist of fine grained granites, coursed granites, porphyritic granites and biotite granites. Granitic rocks occur mainly in the south central to south eastern part of the study area. Commonly associated with these granitic rocks are xenoliths of meta sediments. Sandstone occurring in the study area belong to the Gudumi formation, which is a fluvio-lacustrine deposit overlying the basement complex rocks unconformable [8]. Two types of sandstone occur within the study area: the conglomeritic sandstone and the fine grained sandstone. The conglomeritic sandstone is the dominant sandstone within the study area.

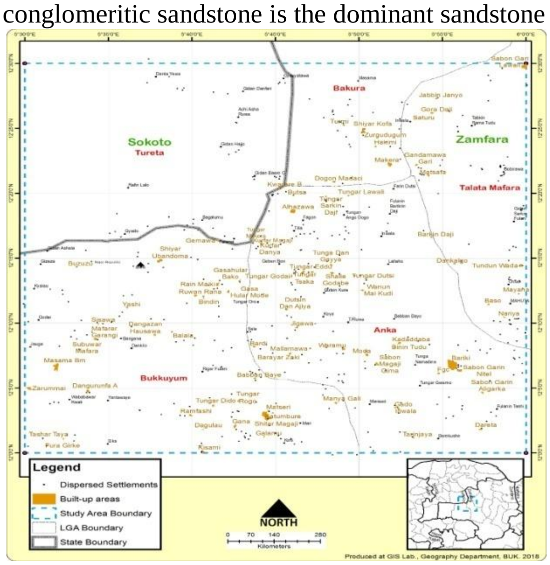


Figure 1: Location Map of the Study Area (GIS Lab. Geography Dept. BUK, 2018)

1.2 Geologic Features of Gold Deposits

The following Geological Indicators are discussed below;

i. Color Changes: In many districts, acidic mineral solutions have bleached the area rocks to a lighter color. This can be an indicator of gold.

ii. Quartz Vein Matter Accumulations: At times, small accumulations of quartz vein Iron Staining & Gossans: Not all veins produce much quartz-gold bearing veins can consist of calcite or mostly sulphide – which often weather into iron stained spots when the pyrites covert to iron oxides. Large amounts of iron oxides like hematite and ironstone can be favourable indicators.

iii. Rock Contact Zones and Faults: Many quartz veins and other hard rock gold deposits occur in zones along faults or at the contact of two different types or rock.

iv. Correct Topography: As a general concept, the coarser gold does tend to hang up farther upstream. In the deserts, most of the best residual placers form in areas with moderate to flat slopes [9,10].

v. Extensions of known Mineral or Placer Areas: Other than pipe shaped bodies, most small scale gold deposits have a linear component. It is fairly common that new deposits can be found along this linear zone of deposition by looking for extensions along the line of deposition.

vi. Similar Geologic Area Nearby: If a certain rock type or geologic environment has been productive for gold in one area, and the same rock type or environment occurs a few miles away in the same mountain range, it may well be worthwhile to investigate [11].

1.3 Climate, Soil and Vegetation

The climate of Anka is warm tropical with temperatures rising up to 38^{o}C between March and May. Rainy season starts in late May to September while the dry season known as harmattan lasts from December to February. Two major soil types, ferruginous tropical soils and lithosols, dominate the local government [12]. The vegetation of the area consists of northern Guinea Savannah, characterized by short and stringy shrubs. [13].

2. MATERIALS AND METHODS

2.1 Data Acquisition

A high resolution aeromagnetic data of sheet number (52) covering the Anka schist belt was used in this paper. The data was acquired by the Nigerian Geological Survey Agency (NGSA). The Agency carried out an airborne magnetic survey of substantial part of Nigeria between 2006 to2007. The flight parameters of theaeromagnetic data are: Flight line spacing (500m), Tie line spacing (2km), Terrain clearance (80m), Flight direction is NW-SE while the Tie line direction is NE-SW.The magnetic data collected were published in the form ½ degree aeromagnetic maps on a scale of 1:50,000. The actual magnetic values were reduced by 33000nT before plotting the contour map. This implies that the value 33,000nT is to be added to the contour values so as to obtain the actual magnetic field at a given point. A correction based on the International Geomagnetic Reference Field, (IGRF).

2.2 Data Processing

The data is that of total field and is in a gridded form as a total magnetic intensity (TMI) map (Figure 2). The data was further processed, enhanced and interpreted with Geosoft (Oasis Montaj), and Surfer. Firstly, on a Geosoft platform the data was projected to Universal Transverse Mercator (UTM) coordinate system Zone 32N using World Geodetic System (WGS) 84 as the datum. The data was then gridded with the minimum curvature method of gridding. In this work the MAGMAP filters that were used in enhancing the magnetic data include reduction to the pole, analytic signal, upward continuation, first vertical derivative and second vertical derivative.

The concept of 2-D analytical signal, or energy envelope, of magnetic anomaliesdeveloped by [14]. The amplitude of the 3-D analytic magnetic field signal at location (x, y) can be expressed as:

$$|A(x,y,z)| = \sqrt{\left(\frac{\partial T}{\partial x}\right)^2 + \left(\frac{\partial T}{\partial y}\right)^2 + \left(\frac{\partial T}{\partial z}\right)^2}$$

where, $A(x, y)$ is the amplitude of the analytical signal at (x,y); T is the observed magnetic field at (x,y).The purpose of the reduction to the pole is to take an observed total magnetic field map and produce a magnetic map that would result, had an area been surveyed at the magnetic pole. Assumption is, all the observed magnetic fields of the survey area are due to induced magnetic effects.

$$L(\theta) = \frac{1}{[\sin(I) + i\cos(I)\cos(D-\theta)]^2}$$

where,

$\theta$is the wavenumber direction;

I is the magnetic inclination;

D is the magnetic declination.

The upward continued ΔF (the total field magnetic anomaly) at higher level (z = - h) is given by:

$$\Delta F\ (x,y,-h) = \frac{h}{2\pi}\iint \frac{\Delta F(x,y,0)dxdy}{((x-x_0)^2+(y-y_0)^2+h^2)}$$

The empirical formula gives the field at an elevation h, above the plane of the observed field (z = 0) in terms of the average value ΔF at the point (x, y, o). Generally, deep-seated magnetic sources are considered to have a low spatial frequency equivalent to large lateral extent or long wavelengths and broad anomalies; while near-surface or shallow magnetic sources result in a high spatial frequency corresponding to short lateral distance or short wavelength and narrow anomalies [15].

The first and second vertical derivative (FVD & SVD) are given as:

$$FVD = \frac{\partial M}{\partial z}\ ,\quad SVD = \frac{\partial^2 M}{\partial z^2}$$

Where M is the potential field anomaly. The vertical derivative was computed from the upward continued data. This is very important to this research as it will bring out the lineaments of interest more obvious. The second vertical gradient can be calculated by exploiting Laplace's equation below:

$$\frac{\partial^2\varphi}{\partial z^2} = -\frac{\partial^2\varphi}{\partial x^2} - \frac{\partial^2\varphi}{\partial y^2}$$

3. RESULTS AND DISCUSSION

The main use of any aeromagnetic and their derivative maps in mineral prospecting is to make geological deduction from them. And from the range of magnetic intensity values of these data, information on subsurface lithology, trend and geological structures can be obtained[16].

3.1 Total Magnetic Intensity Map

Figure 2 is the Total Magnetic Intensity (TMI) map of the study area. The magnetic intensity values of the study area ranges from 32906.1nT (minimum) to 33103.3nT (maximum). From the map, the high magnetic intensity regions are actually areas with low magnetic intensities which represent the meta sediment formation (MS) and the intruded granites, and the low magnetic intensity regions are actually areas with high magnetic intensities which represents the gudumi formations (GF). This misrepresentation is called directional noise that is observed in low magnetic latitude areas due to the inclination of the Earth's magnetic field at these low latitude, this problem is corrected by reducing the total magnetic intensity to the pole where the Earth's magnetic field is vertical. This directional noise problem if not corrected can cause data misinterpretation, hence there was the need for reducing to the pole for easy interpretation of the results.

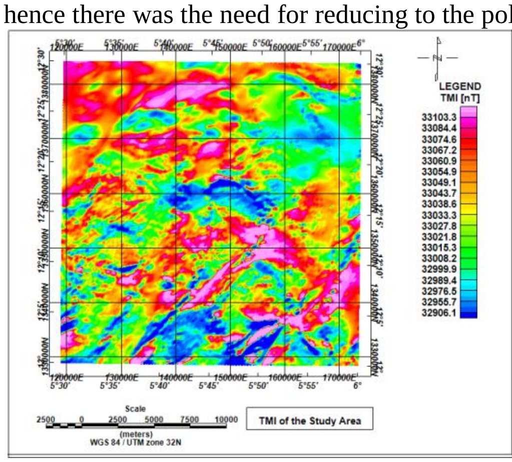


Figure 2: Total magnetic intensity map of the study Area

3.2 Reduction to the Pole

The total magnetic intensity grid were applied to Reduction to the pole, this operation changed the actual inclination to vertical. Reduction to the pole is the process of converting the magnetic field developed by magnetic bodies from the magnetic latitude where the Earth's field is inclined, to the field at the Earth's magnetic pole, where the inducing field is vertical. A basic assumption of the reduction to the pole process is that all bodies are magnetized by induction. From the RTP Map the formation labelled MS are metasediment, those labelled GF are the gudumi formation, those labelled BG are the basin granitoid were trend. The metasediments recorded low magnetic susceptibilities mainly due to the mineral content of the rocks beneath generally muscovite and biotite. The basin granitioid (BG) also revealed very weak concentrations of magnetic minerals because its intrusion destroyed the magnetization around.

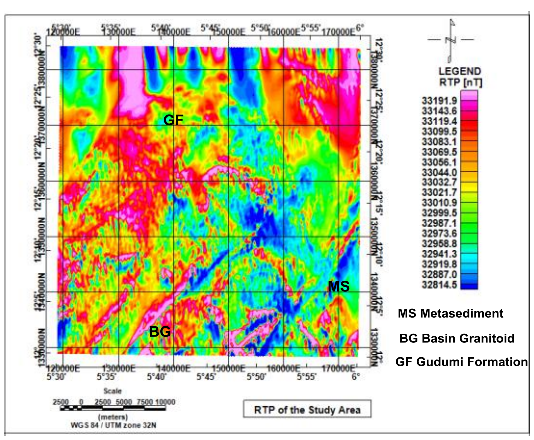


Figure 3: TMI reduced to the magnetic pole (RTP)

3.3 Analytic Signal filter

The Analytic signal filter which is a form of reduction to the pole [17].was applied to the total magnetic intensity field data (TMI) to produce Figure 4showing the NE-SW trending BG magnetic anomaly and several distinct magnetic zones. Comparing this map **(**Figure 4), with the TMI (Figure 2) and the RTP map(Figure 3), the difference is obvious along the edges of the basin granatoid- metasediments contact in the south-west and the central portion of the study area. The analytical signal amplitude maximizes over the edge of the magnetic structures and was used to delineate the edges of lithological units. Metasediments MS (quartzite, phyllite and metaconglomerate), basin granitoid BG (fine and coarse grain granite) and gudumi formation GF (sandstone and alluvial).

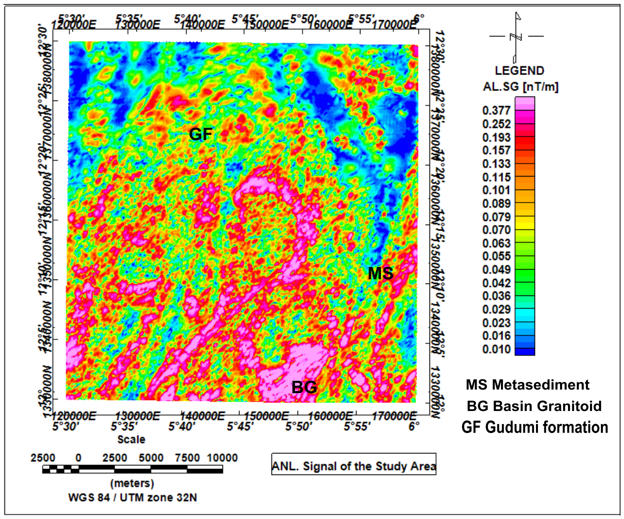
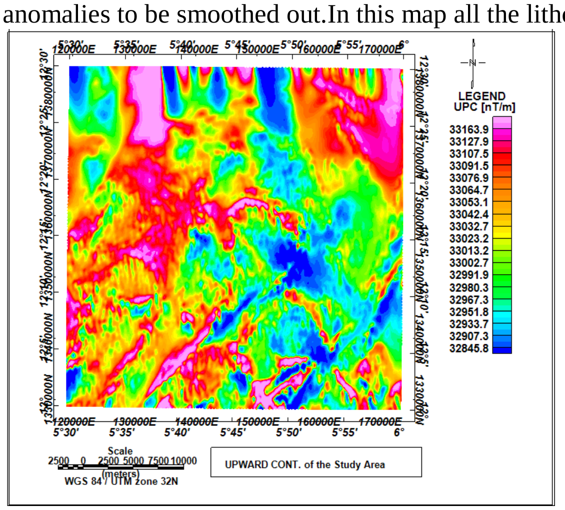


Figure 4**:** Analytic signal map

3.4 Upward Continuation Filter

The upward continuation filter smoothed out high frequency anomalies that originatedfrom shallow source, and enhanced anomalies that originated from deeper structures**.** The process can be useful for suppressing the effects of shallow anomalies when detail on deeper anomalies is required. The reduction to magnetic pole (RTP) grid was upward continued to 100m to see deeper signature coming from deeper structures. This helped high frequency anomalies relative to low frequency anomalies to be smoothed out.In this map all the lithologists and lineament are clearly illustrated



.Figure 5: A 100m upward continuation map

3.5 Vertical Derivatives (VD) Filters

These filters are considered most useful for defining the edges of bodies and for amplifying fault /fracture trends. Result from the first vertical derivative, FVD (figure 6) reveals more of the subsurface structures, three zones were mapped for mining considerations namely zone A between (lat. 12^{o}00$^{'}$to 12^{o}10$^{'}$N and long. 5^{o}30$^{'}$to 5^{o}35$^{'}$E)., zone B between (lat. 12^{o}00$^{'}$to 12^{o}10$^{'}$N and long. 5^{o}40$^{'}$to 6^{o}00$^{'}$E). and zone C between (lat. 12^{o}10$^{'}$ to 12^{o}20$^{'}$Nand long. 5^{o}40$^{'}$to 5^{o}50$^{'}$E). Respectively.

The second vertical derivative analysis provides a means of discriminating local features while suppressing broad and regional structures. SVD has a better resolving power than the first vertical derivative [18] and derivative maps can therefore be used to sharpen the edges of magnetic anomalies and to better their locations. Further investigation through second vertical derivative SVD (figure 7) applied to upward continuation of the total field. Where additional zone D mapped between (lat. $12^o25'$ to $12^o30'$Nand long. $5^o55'$to $6^o00'$E). Which does not appear from first vertical derivative FVD map. The reason why these anomalies are not seen in the original aeromagnetic map is because they have been obscured by stronger effect of broader regional features in the area.

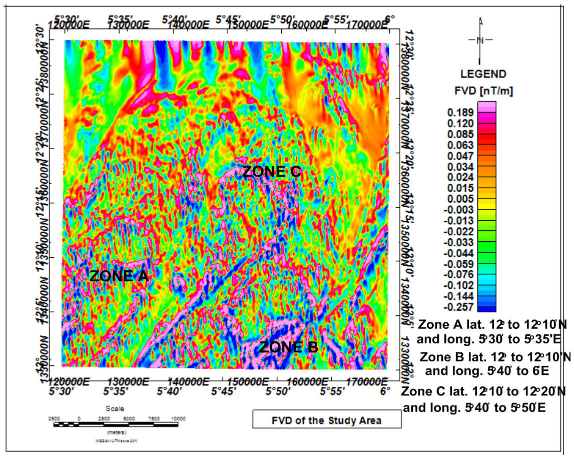


Figure 6**:** First vertical derivative map

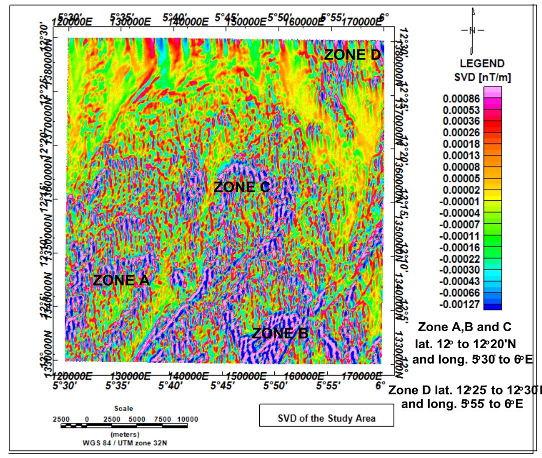


Figure 7: Second vertical derivative of upward continuation

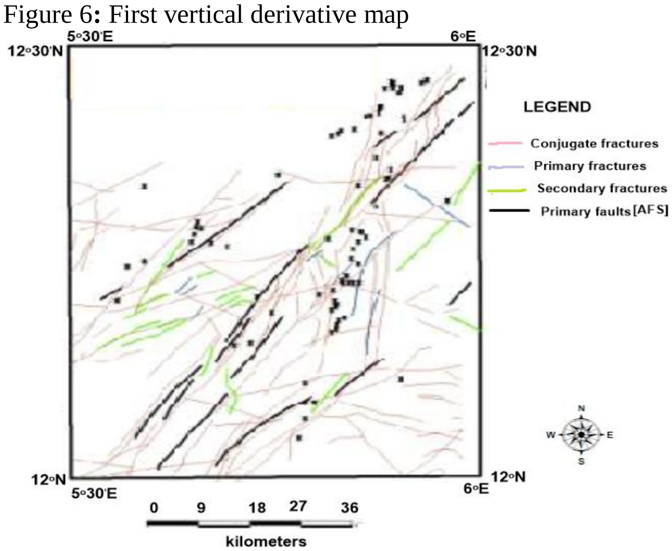


Figure 8: Lineaments map of Anka schist belt in association with the major fault system. (Modified after NGSA, 2009).

4. CONCLUSION

The results of this work have revealed that the rock types and geological units of the study area (Anka), are Gudumi formation (sandstones and alluvial), metasediments (quartzite, phyllite and metaconglomerate) and the basin granitoids (fine and coarse grain granites) which intruded were clearly mapped. From the NW through the central parts of Anka are dominated with sandstone and alluvial. The southeastern parts are mapped to be mainly associated with metasediments with pockets of weathered regolith and felsic sediment. The first vertical derivative, FVD (figure 6) reveals more of the subsurface structures, three zones were mapped for mining considerations namely zone A between (lat. $12^o\,00'$to $12^o10'$N and long. $5^o30'$ to $5^o35'$E)., zone B between (lat. $12^o00'$to $12^o10'$N and long. $5^o40'$to 6^oE). And zone C between (lat. $12^o10'$ to $12^o20'$Nand long. $5^o40'$to $5^o50'$E). Respectively. Further investigation through second vertical derivative SVD (figure 7) applied to upward continuation of the total field. Where additional zone D mapped between (lat. $12^o25'$ to $12^o30'$Nand long. $5^o55'$to 6^oE). This does not appear from first vertical derivative FVD map. The zone signpost mineral trends in the formation, this coincide with the lineament map of the study area obtained from Nigerian Geological Survey Agency (NGSA). These zones are major fracture systems and play a pivotal role in the localization of gold mineralization in the study area.

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