Geological and Magnetic Geophysical Investigations of the Quartz-Vein Gold Mineralization in Some Parts of Ayegunle Sheet 226nw, North Central, Nigeria

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Abstract
The study area is predominated by granite-gneiss, mica schist, leucocratic micro granite and quartzites. The Pan African orogeny left an imprint of structural similarity upon the rock units. The granite-gneisses are found as small belts within the study area, and hosting the quartz-veins. The metasediments are fractured and folded in places. The dominant fold axes and quartz vein intrusions trend NNE-SSW parallel to the regional foliation of the rocks. The emplacement of the quartz vein is associated with the generalized strike direction of quartz vein and host rocks. The structural settings suggest that the emplacement of gold mineralization occurred during Late Pan African orogeny. Geophysical investigations using high precision ground aerial magnetic has been applied in some parts of Ayegunle sheet 226NW, North Central, Nigeria aimed at delineating areas with high magnetic anomalies, magnetic structures and possibly exploration targets for quartz-vein gold mineralization. The geophysical survey resulting in the ground magnetic data was conducted for magnetic element exploration. The total magnetic intensity was applied to identify regional magnetic anomalies, magnetic structures (faults) and structural trends. Magnetic data was gathered using a GEM system GSM-19T proton precession magnetometer at a nominal station spacing of 10 metres. Grid location information was provided by Garmin system UTM datum WGS 84, Zone 32N coordinates and elevation data as meters above sea level in an excel spreadsheet. Several areas of total magnetic field was interpreted low as reflecting high magnetic susceptibility bodies and possible quartz vein gold or sulphide mineralization targets. Total Magnetic Intensity data ranging from 33238.5 – 33261.1nT are taken along survey traverses (normally on a regular grid) used to identify metallic mineralization that are related to magnetic materials (normally magnetite and/or pyrrhotite). Two types of magnetic trends are identified. Firstly, there are several NW-SE arcuate lineations that roughly coincide with some of the geologically mapped epithermal/vein trends. These magnetic trends possibly delineates structural breaks or geological contacts related to these exploration targets. Secondly, there are indications of a major structural break trending northerly through the centre of the survey area. While northerly trending magnetic features are not clearly delineated at these low latitudes, they sometimes appear as subtle breaks in easterly trends or as a series of monopole and/or dipole anomalies.
Keywords: Granite-gneiss, Mica schist, Leucocratic micro granite and Quartzite, Magnetic anomalies, Quartz-vein gold

1. Introduction

Mineral exploration is a sequential process of information gathering that assesses the *mineral* potential of a given area. There are a lot of geophysical survey methods which include gravity, magnetic, radiometric, seismic, electrical resistivity etc. Each of the above survey method has a unique operative physical property like density, magnetic susceptibility, radioactivity, propagation or velocity of seismic waves, electrical conductivity of the Earth (Kearey & Brooks, 2002). Aeromagnetic survey has been recognized as a principal mapping tool for materials that are strongly magnetized (Kearey & Brooks, 2002). Magnetic method seeks to probe the geology of the area due to the differences in the geomagnetic field. These differences are as a result of the magnetic features of the rocks subsurface (Kearey & Brooks, 2002). Magnetic surveying has played a major role in the delineation of both metallic and none metallic minerals (Onyedim, 2007). Mapping of appropriate stratigraphic horizons and identification of suitable structures, such as faults, folds, intrusions etc. are important aspects of the interpretation of magnetic data (Burger *et al.,* 2006). Knowledge of the forms of anomalous responses due to different source geometry is fundamental to the estimation of magnetic source boundaries (Kayode & Adelusi, 2010). TMI is generally a reflection of average magnetic susceptibility of broad, large scale geological features (Li, 2008). Reduction to the equator is used in low magnetic latitudes to ensure that the anomalies are correctly positioned on their causative bodies (Oruc & Selim, 2011). Reducing the data to the pole does much the same thing, but at low latitudes, reduced to the pole data may present a less 'honest' view of the data (GeosoftInc). Correct estimation and removal of the regional field from the initial field observations yields the residual field produced by the target sources (Cooper & Cowan, 2006). The extracted residual anomalies are often useful for structural mapping or qualitative interpretation based on visual inspection of the data (Momoh et al, 2008). Residual maps are used extensively to bring into focus local features which tend to be obscured by the broad features of the regional field (Onyedim & Awoyemi, 2007). Similarly, residual maps reveal much more detailed geologic features bringing out subtle magnetic anomalies that result from the changes in rocks types across basement block boundaries (Onyedim, 2007). The ease of magnetization is ultimately related to the concentration and composition of magnetised material contained within the sample (Wemegah *et al.,2009*). A cursory look at magnetic maps would present more information about the shape of buried features. However, the information acquired from maps can provide additional details about the specification of underground magnetic anomalies, especially exact locations. Magnetic anomaly depends on the inclination and declination of the body's magnetization generally. Also, we know that the orientation of the magnetic body depends on magnetic north. According to the mentioned issues, Baranov (1957) and Baranov and Naudy (1964) proposed a mathematical approach known as reduction-to-the-pole (RTP) for simplifying anomaly shape and determining the exact anomaly location. Total magnetic intensity (TMI) technique has been applied in the study area. Magnetic data were gathered using GEM system GSM-19T proton precession magnetometer at a nominal station spacing of 10 metres. Grid location information was provided by Garmin system UTM datum WGS 84, Zone 32N coordinates and elevation data as meters above sea level in an excel spreadsheet. The magnetic data are processed and interpreted as a mapping tool to distinguish rock types, identify faults, bedding and alteration zones.

2. The Survey Area

The study area is situated within the North-Central Nigerian Basement Complex (figure 1). It lies between Latitudes 08° 22' 41.98" N - 08° 19' 44.96" N and Longitudes 06° 11' 26.95" E - 06° 14' 30.84" E. The site is accessible by Kabba - Ijumu road down to Ayetoro gbede junction to other localities with a minor road and a lot of footpaths. The study area is moderately hilly, interrupted by ridges (like Guguriji and Ihale ridge) of up to 350m above sea level. These ridges often serve as a divide for the numerous streams and rivers that are in the area (Figure 2). There are two major rivers in the study area namely the Ipala River which is seen to flow in NE-SW direction and Oyi River which flows in NW-SE direction. These rivers with their small tributaries form a more or less dendritic pattern. A humid tropical climate predominates with a mean average annual rainfall in excess of 1434 mm which is concentrated in the rainy season from March to November with a break during August. The mean maximum and minimum temperatures across the project region are over 34°C (in the month of February) and 18°C (in the month of December) respectively (Goh and Adeleke, 1979). The highest relative humidity range within the project area is between 81% and 87% corresponding to the wettest months April through October (Hore, 1970).

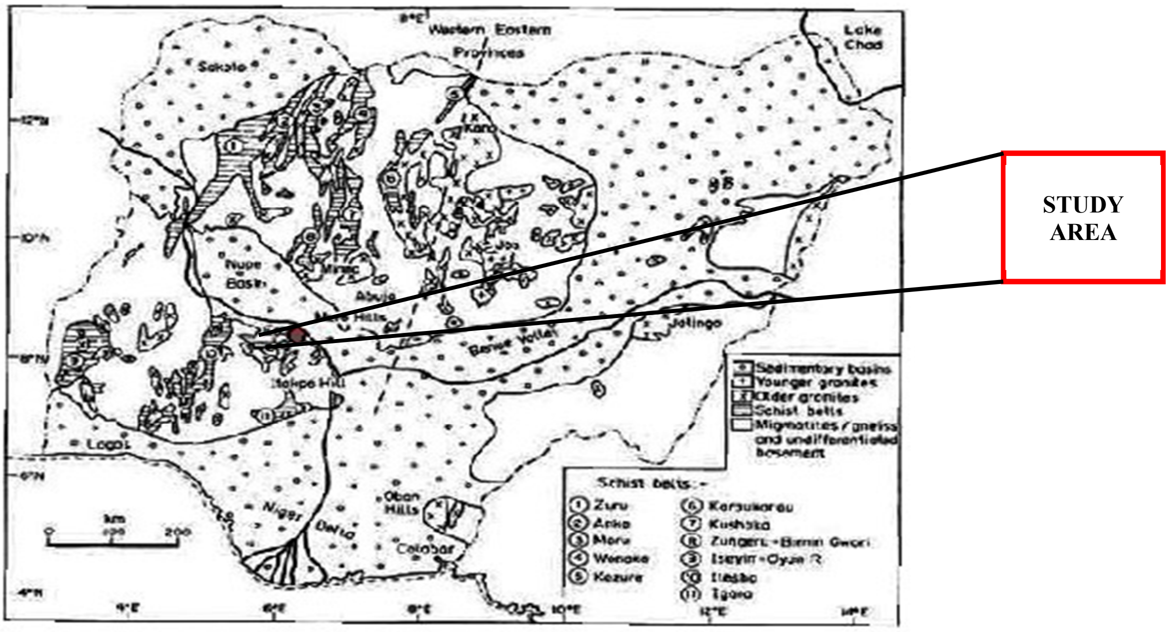

Figure 1: Schist Belt localities within the context of the geology of Nigeria (after Woakes et al,1987)

3. Methods and Materials The present research work includes literature review of relevant published and unpublished work on Nigeria basement Geology and gold mineralization, fieldwork involving geological mapping on a scale of 1:50,000 was carried out using Compass clinometer, Global Positioning System (GPS) and Geologic hammer for rock sampling. The compass clinometer was used to measure trend and dips of lithologies and other structural features on outcrops. Topographic map of the study area were scanned and uploaded into MapInfo software (MapInfo Professional 11.0). It was digitized at scale 1:50,000. Thin section production and petrographic studies were produced for major rocks in the area and analyzed with polarized light microscope. Photomicrographs are uploaded into JMicro Vision 1.2.7 software for modal analysis. Magnetic surveying data was gathered using a GEM systems GSM-19 proton precession magnetometer at a nominal station spacing of 10 metres. Grid location information was provided by Garmin system UTM datum WGS 84, Zone 32N coordinates system. Magnetic data was processed and interpreted using oasis montaj software. The magnetic data was corrected for diurnal variations. In addition to the stacked profile and colour contour displays of the total field data, the magnetic data was processed through upward continuation and reduction to the pole filters.

4. Results and Discussion

4.1 Fieldwork and Petrographic analysis

4.1.1 Field relationships

The study area is part the Nigerian Basement Complex underlain by crystalline rocks, so the geology of the area is the same as that of the Nigerian Basement complex (Oyawoye 1964). Exposures are scanty and highly weathered. The study area is predominated by granite-gneiss, mica schist, leucocratic micro granite and quartzites. Granite-gneiss covers about 70% of the entire area with a sharp contact with mica schist in the north-eastern part of the area. The mica schist covers about 15% of the entire area. The north-western part of the area is covered by the leucrocratic micro granite (about 3%) and granodiorite of about 5% where mapped at the south-western part of the area all in contact with the granite-gneiss. Quartzites (about 2%) appear as intrusions across the granite gneiss along the NE-SW direction. The remaining areas (5%) is occupied amphibolites and syenites which intruded the granite-gneiss in the southern part of the area and quartz veins widely distributed in the entire area mostly mapped at contact and fault zones in the area. The Pan African orogeny left an imprint of structural similarity upon the rock units (Wright and McCurry 1970). The granite-gneisses are found as small belts within the study area, and hosting the quartz-veins (figure 2).

4.1.2 Petrographic analysis

4.1.2.1 Leucocratic micro granite

The sample is light coloured and generally fine grained with occasional medium grained microcline. Medium grained microcline occurs with characteristic cross hatch twinning pattern. It lies within fine grained groundmass. The biotite is brown coloured with moderate relief. The biotite grains are cut parallel to the crystallographic (c-axis) which did not exhibit cleavage. The orthoclase is colourless with low relief but cloudy. It display grey false colour in XPL with oblique extinction (Plate 1)

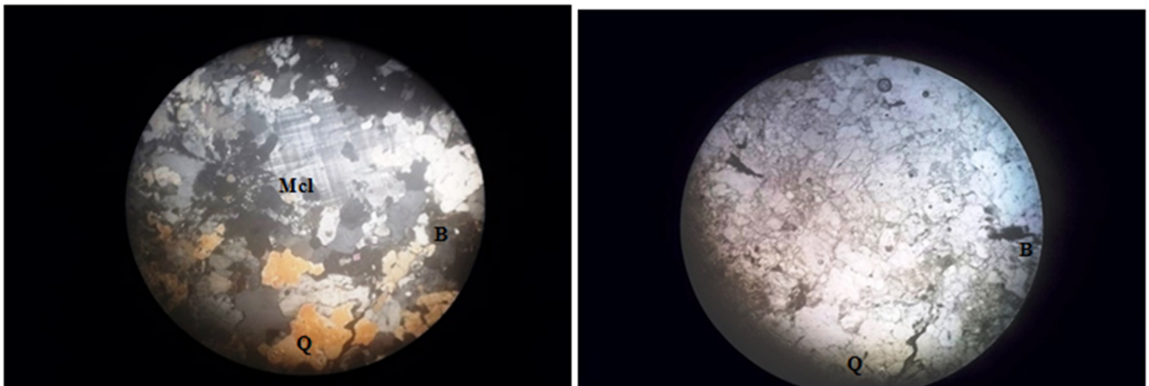

Plate 1: Photomicrograph of leucrocratic micro granite under XPL and PPL (Mag X100 0.90mm)

4.1.2.2 Mica Schist The sample is banded with alternation of dark and light coloured minerals. Felsic minerals present include orthoclase feldspar, quartz and microcline. The biotite is elongate and lineated. This indicates directional pressure perpendicular to the elongation direction. Biotite being ductile responds to directional pressure by elongating. The biotite had moderate to high relief and is brown coloured with perfect basal cleavage in PPL. It also displayed brown interference colour in XPL with straight extinction. The alternation defines the foliation pattern in the rock. Muscovite had moderate relief and is colourless in PPL with perfect one directional cleavage like biotite. It display faint blue and pink interference colour in XPL with straight extinction. The other felsic minerals present are brittle, so are crumble to near mylonitic texture (Plate 2)

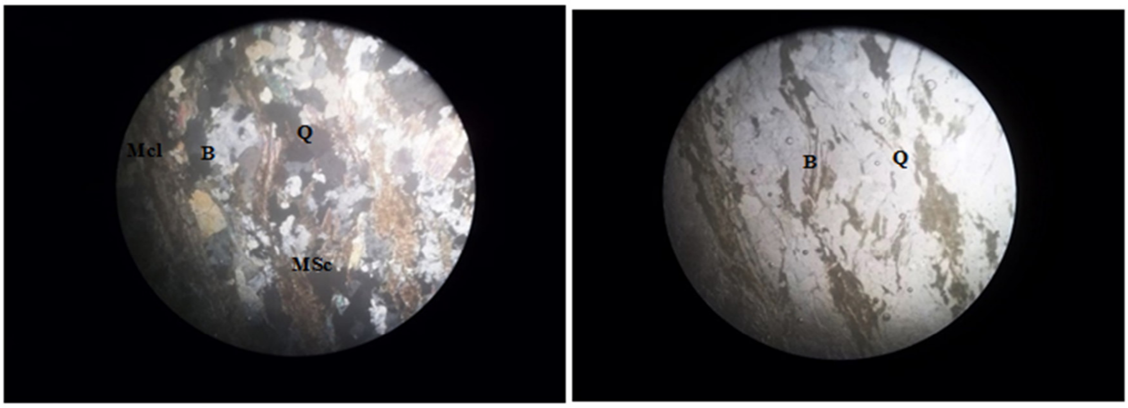

Plate 2: Photomicrograph of Mica Schists under XPL and PPL (Mag X100 0.50mm)

4.1.2.3 Granite-Gneiss

The sample is leucocratic and fine to medium grained. Biotite is the main mafic mineral. It is needle like, light brown but pleicroic from light to dark brown in PPL. The biotite though dispersed is lineated. Muscovite with blue polarisation colour occur as accessory mineral (Plate 3).

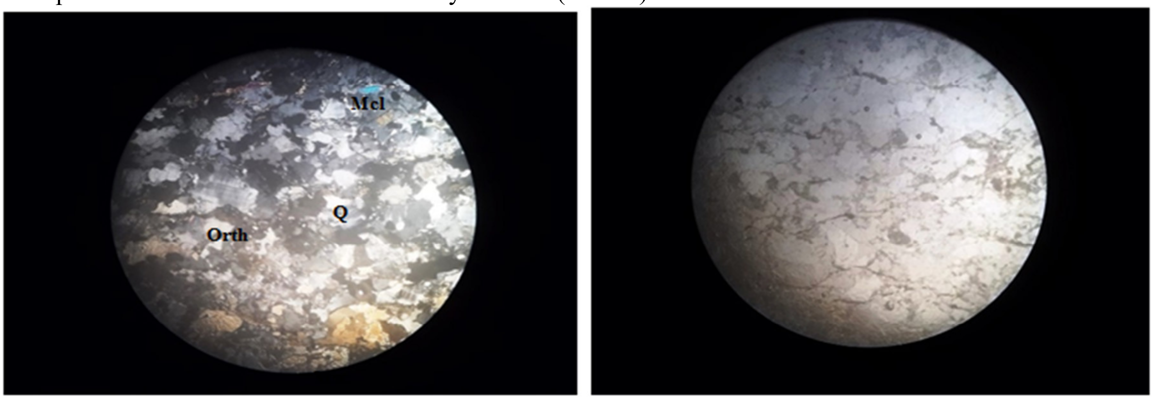

Plate 3: Photomicrograph of Granite Gneiss under XPL and PPL (Mag X100 0.50mm)

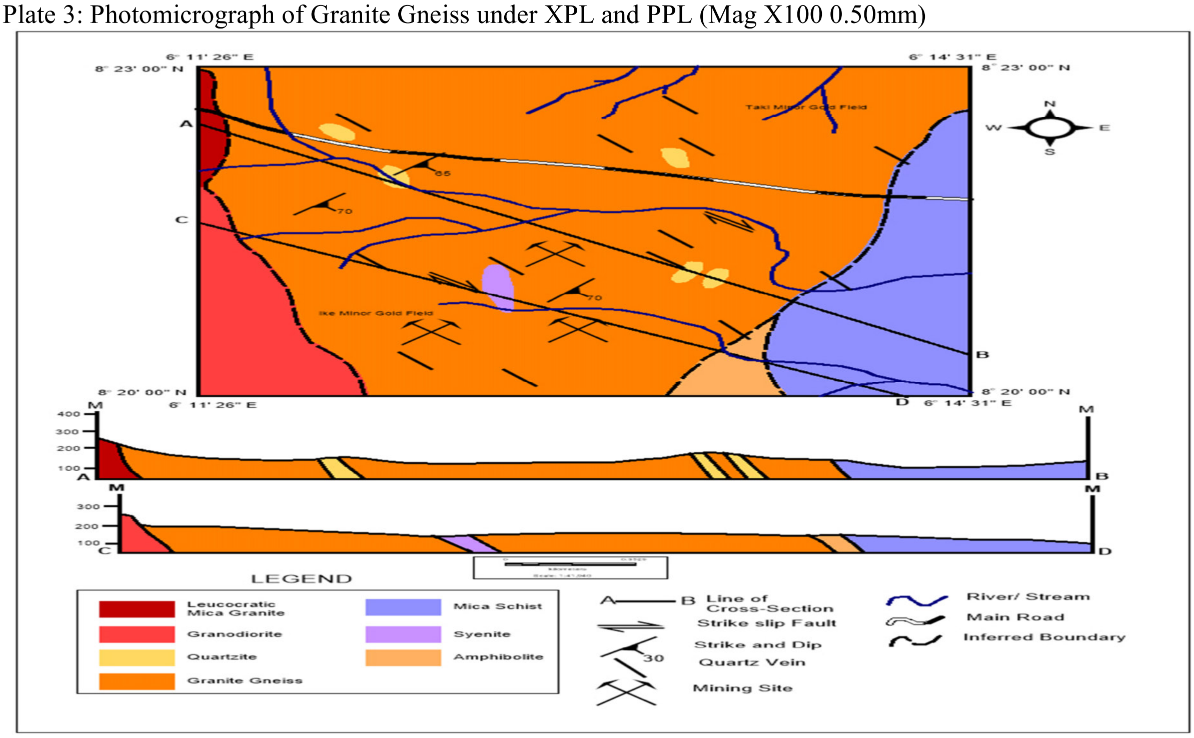

Figure 2: Geological map of the Study Area

Table 4.1: Modal Composition of Minerals in Major rocks of the Study Area

		Percentage (%) Composition					
Rock types	**Coordinates**	**Quartz (Q)**	**Orthoclase (Orth)**	**Plagioclase (Plag)**	**Microcline (Mcl)**	**Biotite (B)**	**Muscovite (MSc)**
Leucocratic Micro Granite	$8^0$20'45''N $6^0$12'35''E	65	15	-	15	5	- = 100
Mica Schist	8^0 21'44''N $6^0$13'50''E	35	15	-	15	25	10 = 100
Granite Gneiss	8^0 22'40''N $6^0$13'22''E	45	15	-	20	10	<10 = 100
Quartzite	8^0 22'30''N $6^0$12'55''E	99	-	-	-	-	- = 99

4.1.2.4 Quartzites

The sample is generally medium to coarse grained with interlocking grain boundaries. The major mineral is quartz (99%). The quartz is colourless with very low relief (as shown in the PPL photo) in PPL. It is whitish (colourless) XPL with wavy extinction on some crystals. Wavy extinction is indicative of deformation. This means the quartz undergo some degree of deformation after emplacement. So, the sample is quartzite or even likely to be quartz vein that explored existing fractures and intruded the host rock (Plate 4).

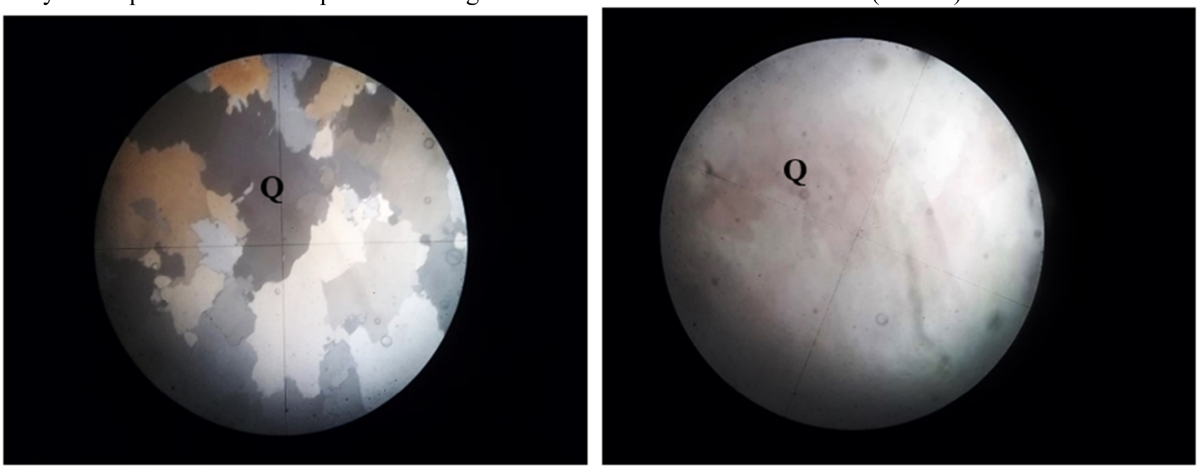

Plate 4: Photomicrograph of Quartzites under XPL and PPL (Mag X100 0.90mm)

4.1.3 Structures

The metasediments are fractured and folded in places. The dominant fold axes and quartz vein intrusions trend NNE-SSW parallel to the regional foliation of the rocks. The emplacement of the quartz vein is associated with the generalized strike direction of quartz vein and host rocks. The structural settings suggest that the emplacement of gold mineralization occurred during Late Pan African orogeny (Oyawoye 1964).

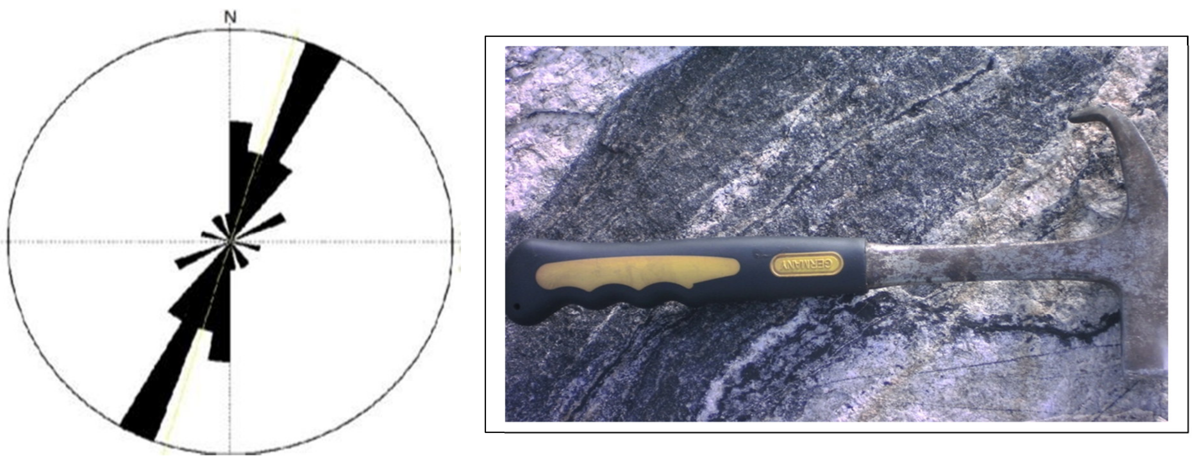

Figure 3: Rose diagram showing trend of foliation in metasediments (mica schist and gniess)
(Trending: NNE–SSW) (8^0 21'44''N $6^0$13'50''E and 8^0 22'40''N $6^0$13'22''E)

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Figure 4: Rose diagram showing joints on metasediments within the study area (8^0 21’44’’N $6^0$13’50’’E and 8^0 22’40’’N $6^0$13’22’’E)

4.2 Geophysical investigations

4.2.1 Total Magnetic Intensity (TMI) anomaly map

The total-magnetic-intensity (TMI) map of the study area was obtained to delineate the subsurface anomaly. Figure 2 indicates TMI with ground magnetic data points. The ground magnetic anomalies range from 33 238 to 33 261 nT and are characterized by both low and high frequencies of anomalies. The map reveals that dipolar (anomalies having positive and negative components) magnetic anomalies have a general E–W direction, which is in the centre and north of the studied area. There are three obvious dipolar magnetic anomalies (two anomalies in the east and west of the centre and one anomaly in the north) in the study area

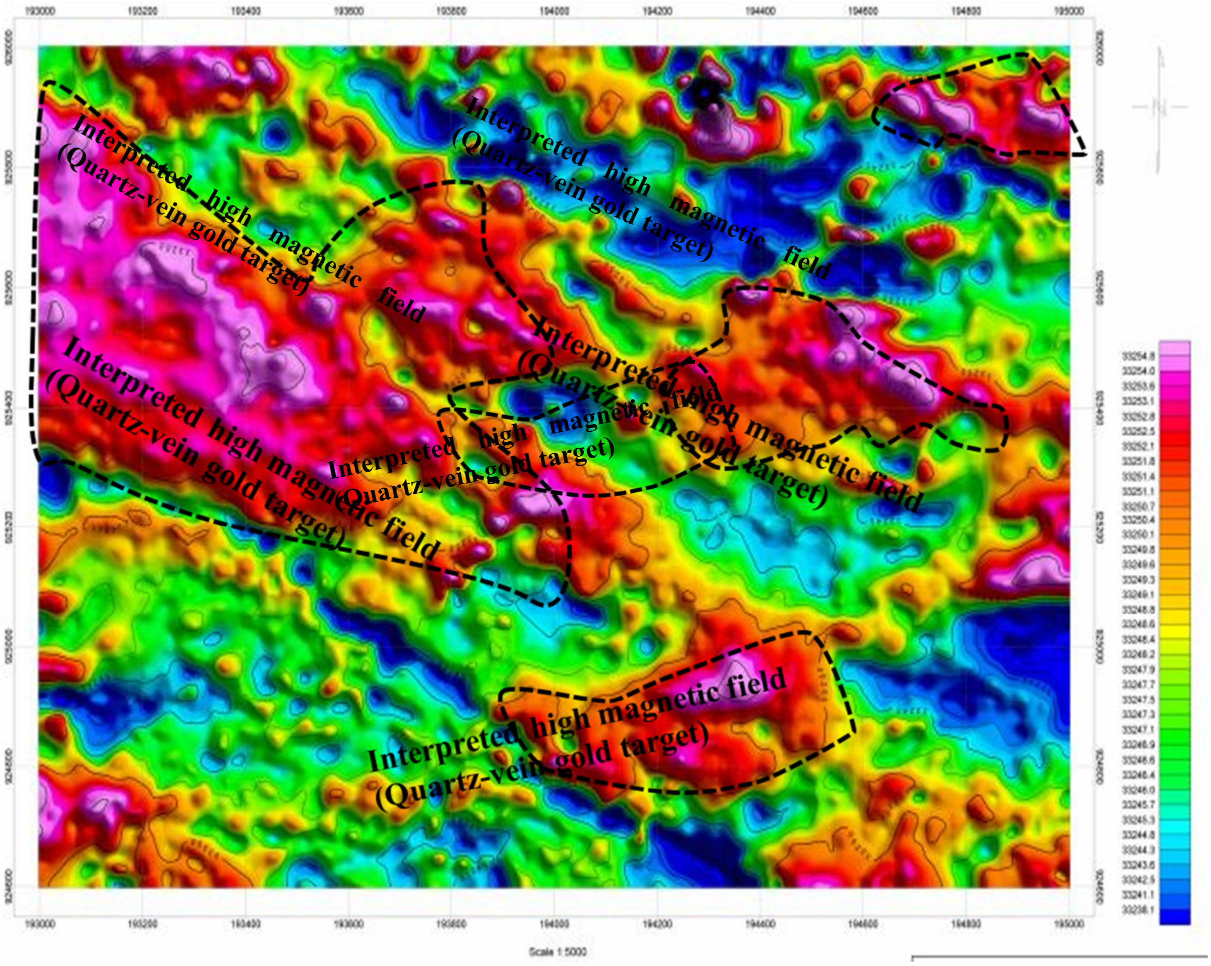

Figure 5: Total Magnetic Intensity (TMI) Map within the NW part of the Study Area

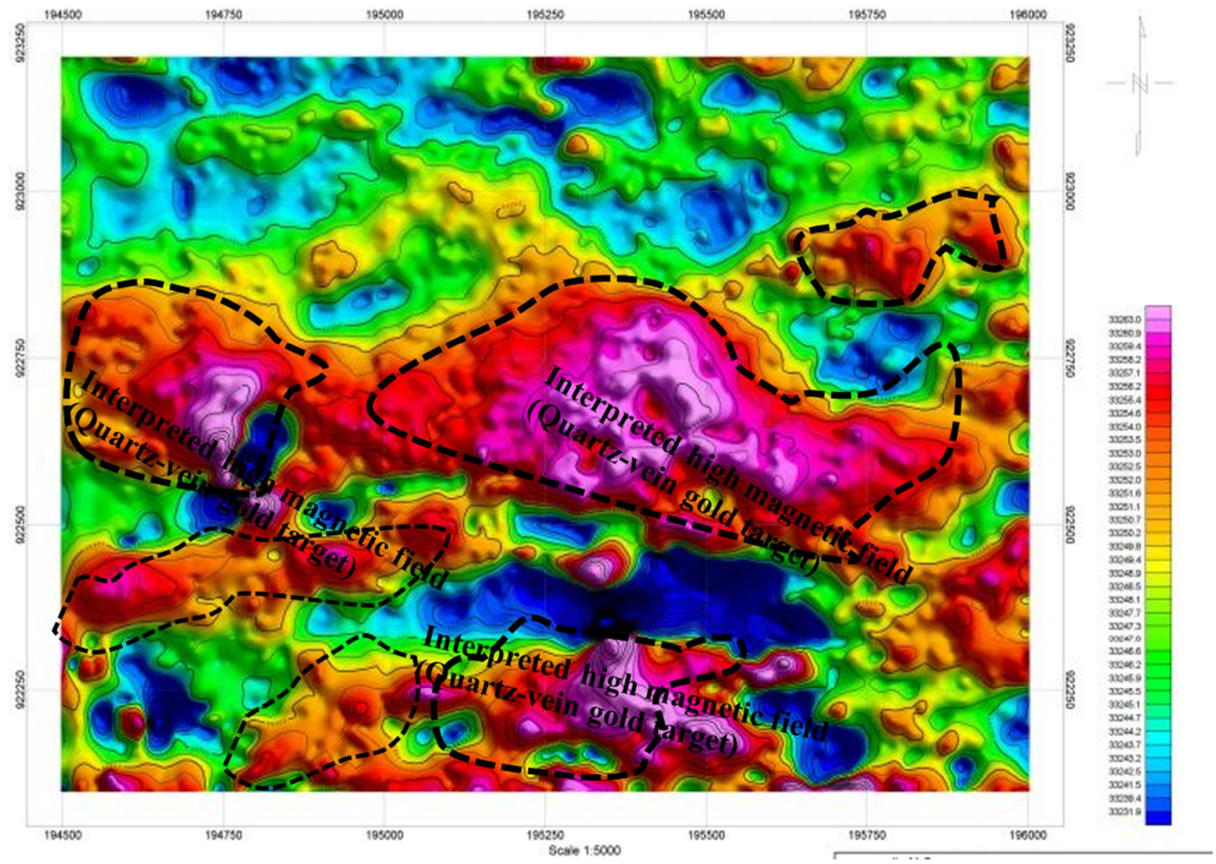

Figure 6: Total Magnetic Intensity (TMI) Map within the SE part of the Study Area

4.2.2 Reduction-to-the-pole technique

A difficulty in interpretation with TMI anomalies is that they are dipolar (anomalies having positive and negative components) such that the shape and phase of the anomaly depends on the part of magnetic inclination and the presence of any remanent magnetization. Because of the magnetic anomaly depending on the inclination and declination of the body's magnetization, the inclination and declination of the local Earth magnetic field, and the orientation of the body with respect to magnetic north, Baranov (1957) and Baranov and Naudy (1964) proposed a mathematical approach known as reduction to the pole for simplifying anomaly shapes. The reduction-to-the-pole (RTP) technique transforms TMI anomalies to anomalies that would be measured if the field were vertical (assuming there is only an inducing field). This RTP transformation makes the shape of magnetic anomalies more closely related to the spatial location of the source structure and makes the magnetic anomaly easier to interpret, as anomaly maxima will be located centrally over the body (provided there is no remanent magnetization present). Thus, the RTP reduces the effect of the Earth's ambient magnetic field and provides a more accurate determination of the position of anomalous sources. It is therefore understood that the total magnetization direction is equivalent to that of the current-inducing field. Before applying the methods, the total field anomaly data were converted to RTP using a magnetic inclination of 52.1 and a declination of 5.1. RTP anomalies show three obvious magnetic anomalies (two anomalies in the east and west of the south and one anomaly in the north) in the studied area, elongated in an approximate E–W direction. The highest class of RTP magnetic anomalies based on the reduction-to-the-pole technique is > 65 nT with 0.6 square kilometres in area. Also, RTP anomalies were classified to different populations based on this method, as illustrated in figure. 7.

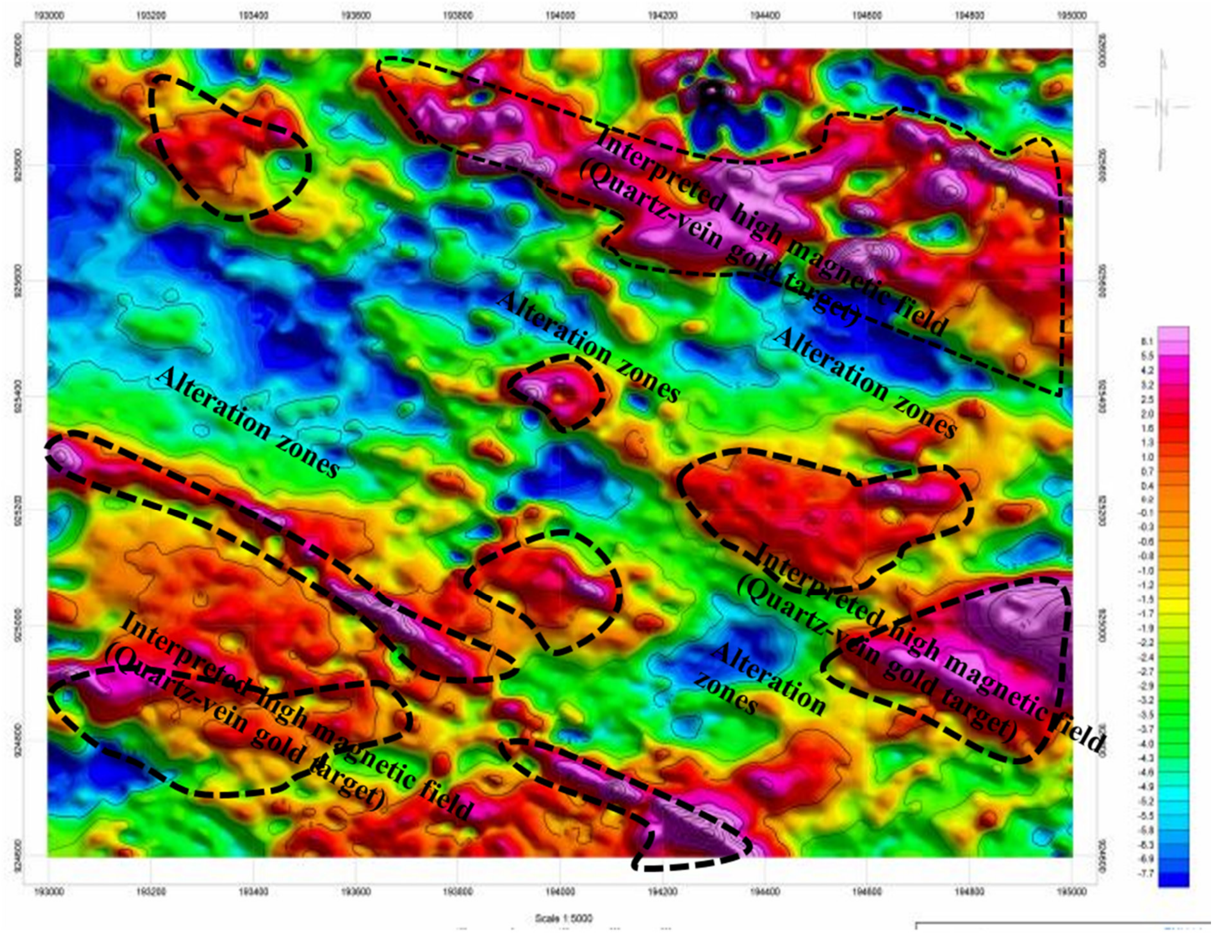

Figure 7: Reduced to Pole (RTP) Map within the NW part of the Study Area.

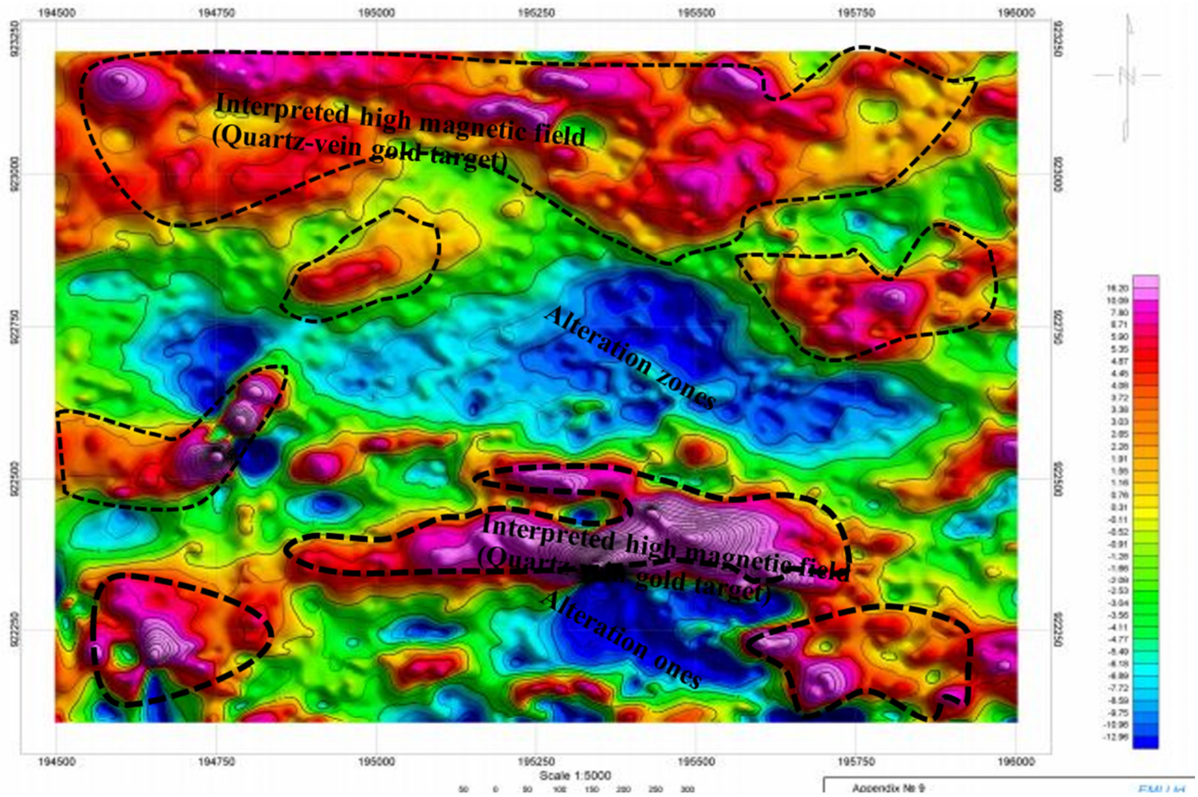

Figure 8: Reduced to Pole (RTP) Map within the SE part of the Study Area.

5. Conclusion

The lithologies of the study area are predominately granite-gneiss, mica schist, leucocratic micro granite and quartzites. The Pan African orogeny left an imprint of structural similarity upon the rock units. The granite-gneisses are found as small belts within the study area, and hosting the quartz-veins. The metasediments are fractured and folded in places. The dominant fold axes and quartz vein intrusions trend NNE-SSW parallel to the regional foliation of the rocks. The emplacement of the quartz vein is associated with the generalized strike direction of quartz vein and host rocks. The structural settings suggest that the emplacement of gold mineralization occurred during Late Pan African orogeny. Several areas of total magnetic field has been interpreted low as reflecting high magnetic susceptibility bodies and possible quartz vein gold or sulphide mineralization targets. One of the larger of these responses coincides with the IP delineated sulphide target north of the NW-SE or Ike prospect. A much smaller magnetic response is associated with the larger IP target north of the base camp. In addition to these responses, there are two other types of magnetic trends that warrant further attention. First, there are several NW-SE arcuate lineations that roughly coincide with or parallel some of the geologically mapped epithermal/vein trends. These magnetic trends might be delineating structural breaks or geological contacts related to these exploration targets. Second, there are indications of a major structural break trending northerly through the centre of the survey area. While northerly trending magnetic features are not clearly delineated at these low latitudes, they sometimes appear as subtle breaks in easterly trends or as a series of monopole and/or dipole anomalies.

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