

RESEARCH ARTICLE

THE CONTRIBUTION OF REMOTE SENSING AND AEROMAGNETISM TO GOLD PROSPECTING: THE CASE OF THE MEIGANGA ZONE, CAMEROON

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Abstract

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Key words:-

Meiganga, Aeromagnetism, Remote Sensing, Landsat 8 OLI/TIRS, Aeromagnetic Line In order to optimize gold prospecting in the Meiganga zone located in the Adamaoua region of Cameroon, aeromagnetic and remote sensing prospecting was carried out in the eastern and southern parts. The remote sensing approach on a Landsat 8 OLI/TIRS image highlighted areas of maximum gold concentration. Thus, ferric ion bearing minerals are located in the North-West, silicate minerals bearing ferrous ions are in the Centre while clay minerals are in the North-East and East. The principal component analysis revealed important structural information. The PCA Spatial Map (PC1, PC2, PC3) showed the plutonic formations composed of anatexis and anatexis granites, vegetation cover (at the date of image acquisition: February 22, 2019), areas of permanent water circulation or accumulation, and metamorphic and sedimentary formations namely gneisses, quartzites, schists and superficial clay formations. A Landsat SRTM (Shuttle Radar Topography Mission) image was also used to enhance the lineaments through the Sobel filter to highlight the geomorphological (cliffs, valleys, ...) and topographic (river network, ridge and drainage segment) structures. The aeromagnetic approach was also important. The study of the modified magnetic field (CM) showed 4 ranges: very high, high, medium and low. The Total Magnetic Anomalies (TMI) of the area are subdivided into 2 ranges; large positive anomalies (221.1-103.0 nT) located in the lower part of NE-SW orientation, small positive anomalies (103.0-(-)89.7 nT) located in the upper part of NE-SW orientation. The reduced total magnetic anomaly at the equator shows a fairly similar distribution to the total magnetic anomaly with the large positive anomalies in almost the entire lower part. Superimposed on the geological map, "Neoproterozoic pre- to syntectonic granitoids (C)" are superimposed on the large positive anomalies and "Neoproterozoic conglomerates, quartzites, sedimentary shales and volcanosedimentary rocks (A)" and "Neoproterozoic syntectonic granitoids (B)" are superimposed on the large and small

positive anomalies. The grid of the reduced residual equatorial anomaly (ARRE) confirms that the local geology is strongly magnetic (gneiss and quartzite). The filters of the derivatives allowed to establish a map of magnetic lineaments of major orientation N045° and minor orientation N130°. The horizontal gadient superimposed on the local maxima showed the presence of deep structures oriented NE-SW. The analytical signal superimposed on the local maxima highlights the metamorphic basement consisting of rocks with strong magnetism. The application of Euler deconvolution localizes the depth of the sources of linear anomalies.

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Introduction:-

The world's natural resources, especially those near the surface, are being depleted and depleted(**Boyle**, 1979). The mineral industry is now moving beyond areas already conquered to more or less complex geological zones such as folded and faulted geological formations and areas with dense vegetation cover (**Blot et al.**, 1978).

Gold is a precious resource and is exploited artisanally or semi-mechanically in Cameroon, but only to a limited extent (Asaah, 2010; Manga et al., 2017). By combining remote sensing and aeromagnetic methods (Pour et al., 2013; Pour and Hashim, 2015a), it is essential to detect zones favourable to gold mineralization in the locality of Meiganga. Since gold is diamagnetic, the presence of minerals such as oxides, sulphides and clay minerals can be used as indicators for the location of hydrothermal alteration zones associated with gold occurrences (Poulsen, 1996).

Remote sensing is widely used in geological and structural mapping (Srivastava and Bhattacharya, 2006; Alonso Contes, 2011; Adiri et al., 2017). The use of this technique becomes more effective when combined with complementary data such as geophysical (Boutirane et al., 2018). In fact, remote sensing can extract multitude of data about the structure and composition of the Earth's surface using satellite image acquisition and interpretation processes. Numerous studies have been carried out using radar remote sensing tools in structural mapping (Mansour and AitBrahim, 2005; Corgne et al., 2010) and in the identification of high potential zones of gold mineralization in a sub-tropical region (Takoudjou et al., 2020). The synergy of geophysical data and radar images makes it possible to gather precise geological informations to determine the fractures network (Ranganai et al., 2008; Ejep et al., 2017; Boutirame et al., 2018). The objective of this work will be to process and interpret satellite images (Landsat 8 OLI / TIRS and Landsat SRTM) and aeromagnetic maps in order to correlate the observed magnetic anomalies, geology, structural and gold (placer) work site data in the study area and to produce a favorability map at the end.

Presentation of the study area

General context

Located in Cameroon in the Adamaoua region, Mbéré department and Meiganga district, our study area is the area delimited by three aeromagnetic sheets crossed by the N°1 with an area of about 1575 km2.

Geomorphologically speaking, our study area belongs to the Adamaoua plateau, located in the middle of the savannah, where the climate is tropical with two seasons, a dry and a rainy one. This locality is characterized by a relief with a convex-concave morphology separated by U and V-shaped valleys or Talwegs (Suchel, 1987). The hydrographic network of the study area is dense and dendritic, with the main collector being the LomRiver (Figure 1A).

Our study area is the area bounded by three aeromagnetic leaves (NB-33-XV-11, NB-33-XV-14, NB-33-XV-15) from CAPAM. This zone is located south and east of the Meiganga district and borders the Central African Republic on its eastern part (Figure **1B**).



Figure 1:- Location map of the study area.

Geological setting

The zone belongs to the granitic and polyclinic Adamawa basement which is a polycyclic complex with a general N130° orientation that extends to the Central African Republic (Ganwa, 2005; Tchameni et al. (2006). This shows that this old complex contains mainly alkaline biotite granites, anatexis granites, biotite gneisses, shales, and quartz and pegmatitic veins (Guiraudie, 1955; Humbell, 1966).

Meiganga is located in the central part of the Pan-African fold belt (Ganwa, 2005), which is a megatectonic structure formed during the Neoproterozoic and is the product of collision between the Saharan metacraton and the Congo craton (Abbelsalam et al., 2002; Ngakoet al., 2008). Thismega-structure covers the main part of the Cameroonian territory and is dominantly composed of pre-Pan-African to syn-Pan-African metamorphic (e.g., gneisses, schists and amphibolites) and igneous rocks (e.g., granite, granodiorite, monzodiorite and monzogranite) (Nzenti et al., 1988; Ganwa et al., 2011; Ganwa et al., 2016). These rocks are locally covered by red colored soils, eluvium, recent alluvium, and colluvium (Kanouo et al., 2018). Some rocks were intruded by quartzo-feldspathic and syenitic veins (dykelets), doleritic and microgranitic dykes probably formed within the fracture network of the

host rocks (Ganwa, 2005; Lasserre, 1961). Shear zones and mylonites are found in some of the metamorphic basement rocks and were interpreted to represent the products of syn-tectonic ductile and cataclastic deformation. Some of the gneisses and amphibolites underwent retrograde metamorphism that led to the formation of green schist facies mineral assemblages (Ganwa, 2005.,Ganwa et al., 2016). Partial melting of gneiss led to the crystallization of leucogranites found in the northern part of Meiganga (Ganwa et al., 2011). The inherited magmatic zircon ages (2339–1887 Ma and 889–675 Ma) for amphibole-biotite gneiss (locally found) indicate that part of the zircons in this rock were sorted from igneous protoliths. Metadioritic basement rock (with age ranging from 619–614 Ma) was formed during syn-tectonic events (Ganwa, 2005; Ganwa et al., 2011).

The study area (Figure 2) consists of magmatic rocks, metamorphic rocks and sedimentary rocks (Ganwa, 2005; Ganwa et al., 2008, Tchameni et al., 2006).

The southern part of Meiganga is mainly covered by two types of metamorphic and magmatic geological formations represented by the rocks of the Lom series, the basic complex with red graphite schists, quartzites, granites (Lasserre, 1961). The eastern part of Meiganga is volcanosedimentary and includes basalts, quartzites and conglomerates (Soba et al., 1991).



Alluvium-eluviumplacer, beachsand Tectonic line and fault Study area Conglomerates, quartzites, sedimentary schists and volcanosedimen. Palaeo-NeoproterozoicGranulites Gneiss Neoproterozoic post-tectonic granitoids Neoproterozoicsyn-tectonic granitoids Neoproterozoic pre to syntectonicgranitoids

Materials And Methods:-

Remote sensing data processing

For this study we used two (02) satellite images, namely :

A Landsat 8 OLI / TIRS image, downloaded from the NASA (National Aeronautics and Space Administration) website earthexplorer.usgs.gov ; Acquired on February 22, 2019 with ID LC08_L1TP_184056_20190217_20190222_01_T1_ANG, this is a multispectral image with eleven (11) spectral

bands, nine (09) for the OLI (Operational Land Imager) instrument (sensor) and two (02) others for the TIRS (Thermal InfraRed Sensor) instrument. Landsat-8 data are acquired in 185 km swaths and segmented into 185×180 km scenes appropriate for regional geological mapping (**Irons et al., 2012; Roy etal.,2014**). **Table 1** shows the characteristics of the Landsat-8 satellite. Landsat-8 data have a high signal-to-noise ratio and 12-bit quantization of the data that permit measurements of subtle variability in surface reflectance (**Irons et al., 2012**).

Spectral bands	Wavelength (µm)	Spatial resolution (m)		
OLIsensor				
Band 1 : Aerosolblue	0,433 à 0,453	30		
Band 2 : Blue	0,450 à 0,515	30		
Band 3 :Green	0,525 à 0,600	30		
Band 4 :Red	0,630 à 0,680	30		
Band 5 :NearInfrared	0,845 à 0,885	30		
Band 6 :shortwaveInfrared	1,560 à 1,660	30		
Band 7 :shortwaveInfrared	2,100 à 2,300	30		
Band 8 : Panchromatic	0,500 à 0,380	15		
Band 9 : Cirrus	1,360 à 1,390	30		
TIRSsensor				
Band 10 : far Infrared	10,30 à 11,30	100		
Band 11 : far Infrared	11,50 à 12,50	100		

 Table 1:- Landsat 8 OLI/TIRS Satellite (sensor) characteristics.

A Landsat SRTM (Shuttle Radar Topography Mission) image, also downloaded from the NASA website earthexplorer.usgs.gov; and with a publication date of April 10, 2015 with ID: SRTM1N06E014V3; it is a monospectral image with a spatial resolution of 30 meters (**Irons et al., 2012**).

Both images were georeferenced to UTM zone 33 North map projection using the WGS84 datum (Irons et al., 2012; Roy et al., 2014).

Data pre-processing

For this study, different softwares were used:

Erdas Imagine and ENVI: which are complete commercial remote sensing software applications capable of preprocessing, enhancing, transforming, and classifyingremote sensing images to extractspatial and spectral information related to geology, such as lithology, hydrothermal weathering, structure, etc.; ArcGis : designed by ESRI, is a suite of software (ArcMap, Arcglobe, ArcCatalog and ArcScene) that has been used for digitizing and joining Excel files; CPI Geomatica: has excellent modules for extracting structural elements; Rose.Net: allowed the graphical representation and calculation of the statistical distribution of the orientation of lineaments (faults, dykes, etc.); Rock Works allowed the synthesis of geological information and geomodelling in rosette.

The pre-processing consisted in correcting the geometric and radiometric distortions (errors) of the platforms and sensors. As for our original data, they underwent three (03) corrections, namely atmospheric correction, noise reduction and data resizing (**Cooley et al., 2002**). Atmospheric correction was performed through radiometric calibration, mathematical correction and dark object subtraction; Concerning noise reduction, we proceeded with MNF (Minimum / Maximum Noise Fraction) transformations (**Research Systems, Inc, 2008**).

For band composition, enhancement techniques applied in this study included colour composition, band ratio, principal component analysis (PCA) and spatial filtering (Singh and Harrison, 1985; Jolliff e, 2002; Jensen, 2005; Cheng et al., 2006; Gupta, 2017; Schowengerdt, 2007). These results are derived from the processing of remote sensing datasets from our study area, and are presented in this section under two aspects: the index aspect, which is intended to specify zones of high gold concentrations (based on hydrothermal alteration representing the surface expression of gold-bearing sulphide and silicate deposits); and the lithological and structural aspect, which could be used to detect related mineral deposits.

Coloured compositions

After all the pre-processing operations performed on the original spectral bands, the "true colour" display (Figure 3) is obtained by performing an RGB colour composite (432); in fact, the image obtained is the one that the eyes would

be able to observe if they were in the place of the satellite sensor. However, the spectral bands of this image are highly correlated, so the resulting image is not very easy to interpret visually. To this end, the results of the IFO calculation allow us to establish the colour compositions between the least correlated bands. The results of the IFM calculation allowed us to obtain the following **table 2**.

Rank	Coloured compositions RGB	IFO
1	567	37833.50
2	256	18875.99
3	357	6083.54
4	456	2294.95
5	145	1173.60
6	245	1035.86

Table 2:- Ranking of IFM calculation in descending order.

Based on the analysis of the six compositions proposed above by the OIF, we found that the most lithologically contrasting (**Inzana et al., 2003; Rockwell and Hofstra, 2008; Mars and Rowan, 2011**), (shades of blue and green) is colour composition 567. This composition (**Figure 4**) shows the red tone as the intensity of the vegetation cover in the area (at the date of image acquisition).



Figures 3 and 4:- True color composition RGB or RGB (432), Lithological discrimination in color composition 567 RGB.

Band ratios

The ratios highlighted are as follows (Pour et al., 2018c; Galvão et al., 2005):

Band 4 / Band 2] (Annex 1 figure 19): ratio highlighting the minerals carrying ferric ions (hematite, magnetite, ilmenite, ...); Band 5 / Band 6] (Annex 1 figure 20): ratio highlighting silicate minerals carrying ferrous ions (Pyroxenes, Amphibole, ...); Band 6 / Band 7] (Annex 1 figure 21): ratio highlighting clay minerals (kaolinite, montmorillonite, alunite, etc.) and/or micas, talc-carbonates.

The interpretation of the three (03) spaciocards (mentioned above) depends on the grey level: the lightest areas are the areas of highest concentration (in minerals corresponding to the band ratio). Following the example of the spaciocard resulting from the 4/2 ratio (appendix 1 figure 19), the minerals (ferric ion carriers (hematite, magnetite, ilmenite, rutile,...) are more concentrated in the Northern, North-Eastern and South-Eastern parts of our study area (Inzana et al., 2003).

By combining the three RGB band ratios (R:4/2, V:5/6, B:6/7), the spaciocard presented in **Figure 5** is obtained, which highlights the areas of maximum concentration for the different band ratios used. For this purpose, we have the following interpretation **table 3**.

Color	Mineral maximal concentration	Band ratio	Location in the study area
Red	Minerals carrying ferric ions	4/2	North-west
Green	Mineralscarryingferrous ions	5/6	Center
Blue	Clay minerals	6/7	North-East, East

Table 3:- Interpretation table of the composition of band report

In this **Figure 5**, the presence of the violet colour illustrates the zones with the highest gold concentration, which are indeed the zones that have been most affected by the hydrothermal alteration. Violet is the colour resulting from the mixing of the red and blue colours(see corresponding minerals in table 4).

Principal Component Analysis (PCA)

To this end, PC1 (Appendix 1, Figure 21) highlights features common to all input bands and often displays important structural information. PC2 (Appendix 1, Figure 21) is orthogonal to PC1 in directional space and highlights visible spectral differences and spectral bands. PC3 (Appendix 1, Figure 21) has the third largest variability orthogonal to the other two PCs (**Gupta, 2017; Schowengerdt, 2007**).

Combining the first three (03) main components results in the composition of PCs containing the most information. For this purpose, the analysis and interpretation of the composition of PC (**Figure 6**) shows: in purple: formations of plutonic types, namely granites and anatexis granites (yellowish purple); in green: the vegetation cover (at the date of acquisition of the image: February 22, 2019); in blue: these are the different areas of circulation or permanent water accumulation; in yellow and white: Metamorphic and sedimentary formations, namely gneisses, quartzites and shales and superficial clay formations; in conclusion, after analysis of the signatures and spectral enhancement of the over-cited data, it appears that the zones with high concentrations of gold are those in yellow (the lighter the yellow, the more gold the corresponding zone contains).



Figures 5 and 6:- RGB image obtained with neobands from ratios 4/2, 5/6 and 6/7; PCA Spatial Map (PC1, PC2, PC3).

Spatial filtering

The mapping of geological lineaments is important for mineral exploration because of the high potential of these lineaments to shelter orebodies; orebodies that are transported anddeposited byascending hydrothermal fluids (**Pour et al., 2018c**). For the geological and geomorphological linear delineation, we used the first main component (PC1) of the PCA (Principal Component Analysis) previously performed, as this component contains most of the non-redundant information (more than 90%). The enhancement of the lineaments which was carried out through the Sobel filter (Appendix 1 figure 22): after analysis, the lineament map resulting from this filter (Sobel) mainly highlights the geomorphological (cliffs, valleys, ...) and topographic (hydrographic network, ridges and drainage segments).

Aeromagnetic data processing

Pre-processing

For this work, we were provided with three aeromagnetic maps in ".PDF" format. These 1/50 0000 scale maps were produced during the aeromagnetic survey of Cameroon carried out by a Canadian Company. This Gold-Cameroon project was carried out in 1986 in collaboration between the Cameroonian government and BRGM. These aeromagnetic data were processed using Geosoft Oasis Monaj 8.4 software; topographic, geological and structural data were processed using ArcGis 10.5 software.

We scanned aeromagnetic maps from ".pdf" to ".jpeg" format using Adobe Acrobat software and then georeferenced the ".jpeg" files on ArcGis. The continuation of our work consisted in the digitization of isomagnetic curves of the georeferenced images to obtain at the end a map of the isomagnetic curves (Appendix 1 figure 17).

Aeromagnetic data pre-processing operations were carried out using ArcGis software. The lines obtained after digitizing are converted into points using the 'Generate point along line' tool with a deviation of 0.0001°, then the attribute table of the layer thus created is accessed and the longitude/latitude of the points is calculated in decimal degrees. At the end of this operation, we obtained a ".shp" file whose attribute table gave us information on the intensity of the modified magnetic field, the longitude and latitude of each point generated.

Modified magnetic field (CM) and theoretical geomagnetic field

The map of the modified magnetic field (Appendix 1 Figure 23) represents the spatial repair of the magnetic field values over the entire Study Area. The magnetic field values are thus represented in several ranges: Very high magnetic field (33526.4 - 33420.1 nT) in magenta and red colours; High magnetic field (33420.1 - 33407.6 nT): in orange color; Mean magnetic field (33407.6 - 33303.2 nT) in yellow and green colours; Weak magnetic field (33303.2 - 33202.4 nT): represented by the colours cyan and blue.

The reference geomagnetic field map of the locality at the time of the magnetic measurements (Appendix 1 Figure 24) is a function of magnetic tilt and declination. This filter is calculated by choosing inclination and declination values from the International Geomagnetic Reference Field (IGRF) normal field model at a time period corresponding to the period of data acquisition.

Total Magnetic Anomalies (TMI)

This map (**Figure 7**) represents the distribution of magnetic anomalies (**Miller and Singh, 1994**) in the Study Area. We can therefore subdivide these values into two ranges of anomalies: large positive anomalies (221.1-103.0 nT): represented by the colours orange, magenta and red. These anomalies are located in the lower part of the map and represent areas where the magnetic intensity is higher than the theoretical magnetic field value. They are oriented North-East and East; small positive anomalies (103.0 - (-)89.7nT): represented by the colours yellow, green and blue. They are located in the upper part of the map and represent the areas where the magnetic intensity is higher than the theoretical magnetic field value. They are oriented East and North-East.

Equator reduction and residual anomaly

The map of the reduced total magnetic anomaly at the equator (Appendix 1, Figure 25) has a fairly similar distribution to the previous map with the difference that the large positive anomalies occupy almost the entire lower part of the map.

The reduced equatorial anomaly map was superimposed with the geological map of the Study Area (Appendix 1 Figure 26) to better understand the distribution of the anomalies. Note that the "Pre- and syntectonicNeoproterozoicgranitoids (C)" are superimposed on the large positive anomalies while the "Conglomerates, quartzites, sedimentary and volcanic schists (A)" and the "Syntectonic Neoproterozoicgranitoids (B)" are superimposed on the large and small positive anomalies.

The residual anomaly grid (ARRE) is obtained by subtracting grids (TMI - AR), (El Gout et al., 2009). The "reduce to magnetic equator" filter is applied to the result to obtain the grid (Figure 8) of the reduced residual anomaly at the equator (ARRE).

Local anomalies are ranged from -128.8 nT to 168.3 nT.Comparing this map with the reduced total anomaly map at the equator (Appendix 1, Figure 25), it can be seen that the magnetic units corresponding to the positive anomalies

(magenta, red, orange, yellow colours) have increased significantly in the lower part of the map but have decreased in the upper part of the map. These variations confirm that, in general, the local geology of our study area consists essentially of highly magnetic rocks such as gneisses and quartzites (**Debeglia**, 2005).



Figures 7 and 8:- Map of the total magnetic anomaly, Map of reduced residual anomalies at the equator (ARRE).

Derivative filters

We performed horizontal derivatives (following X and Y) and a vertical derivative (following Z) on the grid (TMI_R), (**Salem et al., 2008**). However, the aim is to highlight the magnetic lineaments perpendicular to the X plane. Thus the analysis of the map (**Figure 9**) of the horizontal derivative (following X) allowed us to establish a map of magnetic lineaments of the locality (**Figure 10**).

This method, used by several authors (Everaerts and Mansy, 2001; Abderbi and Khattach, 2011), allows on one hand to locate the zones with rapid variation of the magnetic field caused by the lithological change or the presence of geological discontinuities (fractures, faults...), and determine the dip direction of thoses geological structures on the other hand. Indeed, the magnetic anomalies correspond to inflection points which transform after the horizontal gradient calculation into local maxima. These maxima are located above the geological contacts that present magnetic susceptibility contrasts (Van Senden et al., 1990). In order to determine the dip direction of thoses structures, a series of upward continuation has been carried out at different altitudes. For each level the horizontal gradient of the residual magnetic field is calculated and its local maxima are determined. If the structures are vertical, the maxima obtained at each altitude are superimposed.

Horizontal gradient (GH) and analytical signal

On the map of the horizontal gradient superimposed on the local maxima (Appendix 1, Figure 27), it can be seen that the straight contacts are more pronounced in the central and upper parts. There is also a preferential alignment of the maxima in the SW-NE direction. These results suggest the presence of deep structures oriented in this direction.

The map of the analytical signal superimposed on the local maxima (Appendix 1 Figure 28) shows only positive anomalies, unlike the map of the horizontal gradient (Appendix 1, Figure 27), which shows both positive and negative anomalies. This variation could be due to the presence of a metamorphic basement consisting of rocks with strong magnetism (gneiss, quartzite).



Figures 9 and 10:- Horizontal derivative map according to X; surface magnetic lineaments obtained by interpretation of the horizontal derivative map according to X.

Euler's deconvolution

The application of Euler's deconvolution requires knowledge of four parameters (**Reid et al., 1990**): the structural index, the size of the filtering window, the tolerance and the depth of investigation. After several tests, the best model of Euler's solutions was obtained by fixing a structural index of 1.5, a filtering window of 10, a tolerance of 20%. The Euler solution grid illustrates the position and depth of the sources of linear anomalies. In order to better understand this distribution, we superimposed on this grid the maxima of the horizontal gradient and the maxima of the analytical signal (**Figure 11**).

By the Blakely and Simpson method, the interpretation of the result of this superposition is based on three criteria: when the maxima of the horizontal gradient are isolated on the map of the two superimposed methods, they represent the true contacts; when the maxima of the analytical signal and of the horizontal gradient are quasi-parallel and not confused, then the analytical signal represents the true contacts and the horizontal gradient indicates the direction of dip of these contacts; and when the maxima of the two methods are confused, then they represent the vertical contacts. The result of this interpretation is a synthetic map that illustrates the distribution of deep faults in the locality (**Figure 12**). The geological (direction and direction of dip) and geometric (approximate depth and length) characteristics of the deep faults are presented in table 4 in Appendix 2;Table 5 shows activities of CAPAM.



Figures 11 and 12:- Map of Euler solutions superimposed on the maxima of the horizontal gradient and the analytical signal; Deep faults with the Euler solution map superimposed on the maxima of the horizontal gradient and the analytical signal.

Results and Discussion:-

Based on the interpretations of the satellite images, the principal component analysis allowed us to identify several types of geological formations in our study area based on colour. By comparing this PCA map with the geological map of the area, a correlation of the geological formations can be seen (**Figure 13**).



Figure 13:- Comparison of the geological formations obtained.

A formations are the metamorphic and sedimentary types, namely gneisses, quartzites and shales and volcanosedimentary, while B formations are the plutonic types, namely anatexis and granitoid granites (Nzenti et al., 1988; Ganwa et al., 2011; Ganwa et al., 2016).

By superimposing the lineaments obtained by Sobel 7.7 filter (at high density) on our PCA map (Appendix 1 figure 29), we can see that these lineaments completely cover the yellow formations. This shows once again that these

formations are located at the level of major accident zones such as faults, fractures, river circulation zones, hence the alteration zones of hydrothermal deposits favourable for gold mineralization (**Ganwa**, 2005., **Ganwa et al.**, 2016).

By superimposing on the geological map the data of the gold workings, the major superficial lineaments of the Sobel 7.7 filter, the deep Euler faults and the superficial magnetic lineaments of the horizontal derivative X we obtained the following synthesis map in **figure 14**.

The data from alluvial and eluvial gold workings are much more concentrated on formations of metamorphic and sedimentary types, i.e., quartzites, conglomerates, sedimentary schists and volcano-sedimentary shales. We can also notice by correlation of the structures (deep faults and superficial lineaments) highlighted on our map that the superficial magnetic lineaments of the horizontal derivative X fit exactly several times with the tectonic lines of the existing geological map. We can deduce that the structures obtained have a good accuracy. However, in order to confirm and make these results reliable, it will be necessary to make a field descent and do the detailed mapping. In addition, the favourability map (**Figure 15**) based on the structural synthesis map already gives us a fairly precise knowledge of the zones favourable for primary gold mineralization in our study area.



Figures 14 and 15:- Synthesis map of the data of the different structures; Favorability map of the study area.

Conclusion:-

The identification of potential gold sites using a combination of remote sensing methods and aeromagnetism to detect zones of maximum gold concentration in the Meiganga locality is promising. We have shown the correlation between the existing geological formations and those obtained from remote sensing methods, with emphasis on the alteration formations of hydrothermal deposits, and we have created a favorability map containing all the structures obtained from the processing of aeromagnetic data and satellite images.

Based on these results, we can already say, subject to detailed mapping, that the lineament and fault overlay zones as well as the zones of metamorphic-type formations are likely to contain a primary source of mineralization.

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Appendix I:-



Figures 17 and 18:- Isomagnetic contours of the study area; Spaciocard (ratio 4/2) showing the index of iron-ion bearing minerals (maximum concentration in clear areas).



Figures 19 and 20:- Spaciocard (ratio 5/6) showing the index of silicate minerals carrying ferrous ions (maximum concentration in light areas), Spaciocard (ratio 6/7) showing the index of clay minerals (maximum concentration in light areas).



Figure 22:- Linear map obtained by Sobel filtering.



Figures 23 and 24:- Modified magnetic field map, Theoretical magnetic field map.



Figures 25 and 26:- Map of the reduced total magnetic anomaly at the equator, Geological map superimposed on the map of the reduced total magnetic anomaly at the equator.



Figures 27 and 28:- Shaded relief horizontal gradient map and local maxima (black dots represent local maxima); Shaded relief analytical signal map and local maxima. Grey dots represent local maxima.



Figure 29:- Lineament (directional filter) overlay on the PCA spaciocard.

Appendix 2

Table 4:- Geological and	geometric	characterization	of deep faults.
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	0	·····	
Symbol	Trend	Dip line	Approximate depth (m)
FV_F1	N090E	Vertical	2010
FV_F2	N090E	Vertical	930
FV_F3	N090E	Vertical	1173
FV_F4	N090E	Vertical	1092
FV_F5	N090E	Vertical	1133
FV_F6	N090E	Vertical	1140
FV_F7	N090E	Vertical	1323
FV_F8	N090E	Vertical	1760
FV_F9	N090E	Vertical	1220
FV_F10	N090E	Vertical	782
FV_F11	N090E	Vertical	843
FV_F12	N090E	Vertical	1429
FV_F13	N090E	Vertical	1020
FV_F14	N090E	Vertical	1260
FV_F15	N090E	Vertical	1590
FV_F16	N090E	Vertical	750
FV_F17	N090E	Vertical	880
FV_F18	N090E	Vertical	739
FV_F19	N090E	Vertical	1990
FV_F20	N090E	Vertical	1370
FV_F21	N090E	Vertical	1270
FV_F22	N090E	Vertical	970
FV_F23	N090E	Vertical	793
FV_F24	N090E	Vertical	880
FV_F25	N090E	Vertical	940
FV_F26	N090E	Vertical	1147
FV_F27	N090E	Vertical	978
FV_F28	N090E	Vertical	710
FV_F29	N090E	Vertical	731
FV_F30	N090E	Vertical	1222
FV_F31	N090E	Vertical	1092

FV_F32	N090E	Vertical	896
FV_F33	N090E	Vertical	934
FV_F34	N090E	Vertical	1130
FV_F35	N090E	Vertical	980
FV_F36	N090E	Vertical	896
FV_F37	N090E	Vertical	870
FV_F38	N090E	Vertical	840
FV_F39	N090E	Vertical	776
FV_F40	N090E	Vertical	790
FV_F41	N090E	Vertical	760
FV_F42	N090E	Vertical	740
FV_F43	N090E	Vertical	790
FV_F44	N090E	Vertical	1378
FV_F45	N090E	Vertical	733
FV_F46	N090E	Vertical	1290
FVF47	N090E	Vertical	934
FVF48	N090E	Vertical	880
FVF49	N090E	Vertical	1110
FVF50	N090E	Vertical	1335
FVF51	N090E	Vertical	1332
FVF52	N090E	Vertical	1227
FVF53	N090E	Vertical	1520
FDF1	NE-SW	N40E	1155
FDF2	E-W	N00E	1220
FDF3	NNW-SSE	N84E	1292
FDF4	E-W	N00E	870
FDF5	E-W	N00E	990
FDF6	N135E	N45E	1348
FDF7	E_W	N00E	780
FDF8	N135E	N45E	1534
FDF9	N088E	N02E	943
FV= vertical faultFD= directional fault			

Table 5:- Gold Mine Workings Data for the Study Area (Capam, 2019).

Name of society	Location	Coordonates	Content
1) Socadior 2	Batoua/So'o	N06°17'01,7'' E014°42'09,7''	0,8-1,2 g/t
2) Socadior3	Batoua/So'o	N06°17'0,4'' E014°41'02,4''	0,8-1,2 g/t
3) SCEM 10	Batoua/So'o	N06°18'25,6'' E014°38'40,3''	0,8-1,2 g/t
4) HMC 1	Kombo-Laka/Fell	N06°24'46,7'' E014°37'08,5''	1,5-2 g/t
5) HMC 2	Kombo-Laka/Fell	N06°24'42,1''E014°36'25,0''	1,5-2 g/t
6) Socadior 1	Kombo-Laka/Wantia	N06°25'45,4''E014°37'09,2''	1,5-2 g/t
7) Socadior 4	Kombo-Laka/Wantia	N06°25'56,2'' E014°38'26,8''	1,5 -2 g/t
8) Hingtay 1A	Mamawassandé	N06°22'10,9'' E014°34'11,5''	1-1,5 g/t
9) Hingtay 1B	Mamawassandé	N06°22'12,6'' E014°34'11,1''	1-1,5 g/t
10) Hingtay 4	Mamawassandé	N06°21'37,5'' E014°34'55,5''	1-1,5 g/t
11) Tiang X.M.	Mamawassandé	N06°21'39,4'' E014°34'43,7''	1-1,5 g/t
12)Hingtay 5	Batoua/So'o	N06°18'22,6'' E014°38'30,0''	0,8-1,2 g/t
13)Hingtay 3	Batoua/So'o	N06°18'20,4'' E014°37''59,5''	0,8-1,2 g/t
14) SCEM 8	Batoua/So'o	N06°18'58,3'' E014°37'48,2''	0,8-1,2 g/t
15)Weige	Batoua/So'o	N06°19'09,5'' E014°37'23,7''	0,8-1,2 g/t
16) AαC Intergrpe 1	Mborguene/Foum	N06°18'30,6'' E014°32'15,5''	1,5-2 g/t
17) AαC Intergrpe 2	Mborguene/Foum	N06°18'32,2'' E014°32'00,2''	1,5-2 g/t