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Interpretation of Airborne Radiometric Data of Part of Middle Benue Trough of Nigeria for Mineral Deposits

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Abstract
Aeroradiometric study of Makurdi, Gboko, Kastina-Ala and Akwana was carried out to delineate prominent radiometric anomalies for solid minerals within the study area. This study area which is in the Middle Benue trough of Nigeria lies within latitude $7^0\ 00'$ to $8^0\ 00'$ North and longitude $7^0\ 30'$ to $8^0\ 30'$ East with an area of about 12,100km^2. The four sheets (251, 252, 271 and 272) of radiometric data were merged into a single composite data sheet which formed the study area. The merged data were imported into Oasis Montaj 8.4 for gridding, using the minimum curvature method, to produce an enhanced observed radiometric distribution of the three primary radioelements (Potassium, Thorium and Uranium). Interpretation of the ternary image of the primary radioelements gave the range of the count rate of Potassium, Thorium and Uranium as 0.11-2.75%, 6.79-27.71ppm and 1.69-6.21ppm respectively. The threshold value of the total count was statistically estimated as 41 cps. The radiometric ternary map delineated areas of radiometric anomalies and their relative abundance. From the interpretation result, parts of the study area with highest radiometric mineralization were identified as Katsina-Ala and Akwana.

Keywords: *Radiometric Anomalies, Total Count, Threshold Value, Ternary Map, Mineralization, Middle Benue Trough.*

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I. Introduction

Airborne radiometric survey has remained one of the most economical methods of conducting a geophysical reconnaissance study, especially in difficult terrains or in-accessible regions. The method provides important information for mineral exploration by detecting and mapping natural radiometric emanations of gamma rays. Although a good number of naturally occurring elements are known to be radioactive, all detectable gamma radiation from the earth comes from natural decay of Uranium (U), Thorium (Th) and Potassium (K). Only these three elements can produce gamma rays of sufficient energy and intensity to be measured in gamma ray spectroscopy due to their relative abundance in some natural environments.

Airborne radiometric survey is useful in measuring the variations in the radioactive mineral composition in order to identify lithological changes. This entails measuring naturally occurring radioelements that are present in rock and soil profiles. The elements U, Th and K are found as trace elements in rock and they decay naturally to give off gamma rays. Hence the basic objective of radiometric surveys is the determination of relative or absolute amount of U, Th and K in the rocks and soil.

This study is based on quantitative interpretation of aeroradiometric data over Makurdi, Akwana, Gboko and Katsina-Ala with a view to identifying the areas with prominent radiometric anomalies. Such anomalies as Uranium abundance can be useful in geothermal electricity generation in Nigeria.

Geology of the Study Area

The study area lies within latitude $7^0\ 00'$ to $8^0\ 00'$ North and longitude $7^0\ 30'$ to $8^0\ 30'$ East with an area extent of approximately $12{,}100\ \text{km}^2$ and is located in the Middle Benue Trough of Nigeria. Figure 1 is the geological map of Nigeria showing the location of the study area. The Middle Benue Trough experienced two major types of sedimentation cycles. The first sedimentary cycle deposited shales and limestones (Albian-Cenomanian) along Wukari and Akwana. These sediments lie unconformably on the Precambrian basement rocks. The second sedimentary cycles started from the Upper Coniancian to late Maastrichtian, depositing shales, limestones, sandstones and ironstones around Lafia, Akwana and parts of Shendam[1]. The Keana sandstone is made up of poorly sorted feldspathic coarse grained pebbly sandstones that sometimes contain pebbly conglomerates[2,3]. In the Keana-Awe area, the overlying Awe formation consists of flaggy, whitish coarse-medium grained sandstones, interbedded with carbonaceous shale, clay and sandy limestones[2,3]. The lower part is associated with brine springs which are seen to issue near Awe[3]. Overlying the Awe formation are unnamed marine deposits of Lower Turonian age which only rarely outcrop[2,4]. They consist mainly of shale, clay, siltstone and shaley limestone which are known to be mixed with volcanic materials to the south and south-west of Awe[2]. The Lafia formation is the youngest reported formation in the Middle Benue and consists of coarse grained ferruginous sandstones, red loose sand, flaky mudstones and clay[2,3,4,5]. Figure 2 shows the stratigraphic succession in the Benue trough[6].

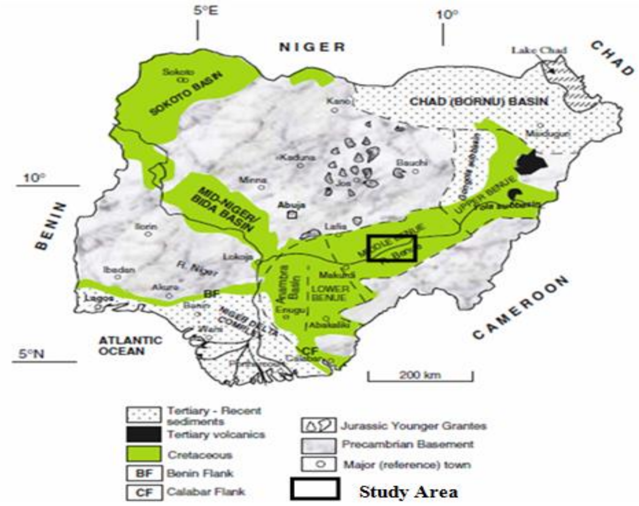

Figure 1. Geological map of Nigeria showing the study area[6].

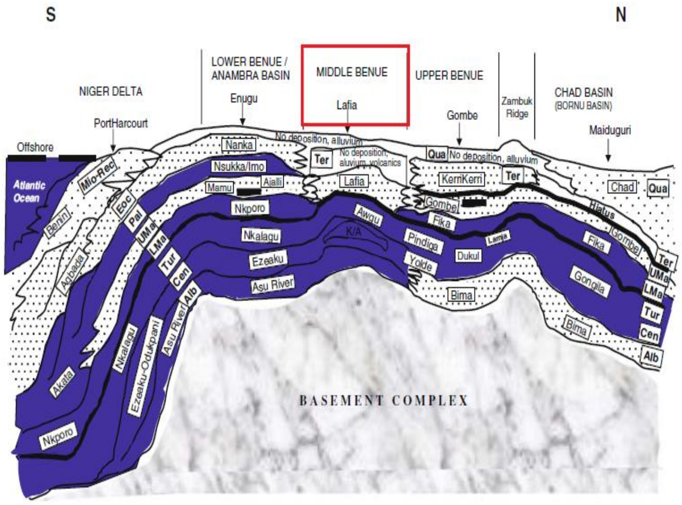

Figure 2. Stratigraphic succession in the Benue Trough[6].

II. Materials And Method

Materials.

The data used for this study were obtained from Nigeria Geological Survey Agency (NGSA). The survey was carried out by Fugro Airborne Surveys Limited in 2008. The data which were presented in digital form as a composite grid of 1:100,000 covering the study area were acquired at flight elevation of 80m, line spacing of 500m and tie line spacing of 5000m. A line direction of 135/315^{o} was also utilized for the survey. Four aeroradiometric sheets of Makurdi (sheet 251), Akwana (sheet 252), Gboko (sheet 271) and Katsina-Ala (sheet 272) were acquired from NGSA.

Method.

The acquired four data sheets were merged into a single composite sheet using Microsoft Excel to form the study area, covering about 12,100 km^2. The merged data were thereafter imported into Oasis Montaj 8.4 for gridding, using the minimum curvature method, to produce an enhanced radiometric distribution of the count rate of the primary radioelements (Potassium, Thorium and Uranium). This generated images for identification and characterization of the radiometric signatures associated with mineralization in the area. A ternary image of the primary elements was produced in which Uranium, Thorium and Potassium were respectively assigned red, green and blue colours.

The quantitative interpretation of the data also involved statistical analysis to estimate, among other parameters, the mean, mode, median, standard deviation, skewness, threshold value and expected mean activity (EMA) of the radioelements in the area.

III. Results And Discussion

The total count rate of the three radioelements (Uranium, Thorium and Potassium) ranges from 1008.61 - 3454.36 cpt as shown in Figure 3. The map shows high total count rate in some parts of the study area, mostly around Katsina-Ala, whereas low total count rate was recorded around Gboko and Makurdi areas. In order to map out the most probable areas of radiometric mineralization, threshold value of the total count concentrations were determined statistically. Table 1 shows the result of the statistical analysis of the radioelements. The threshold value of the total count rate was statistically found to be 2482.37 cpt (Table 1). The area (mostly around Katsina-Ala) where the total count rate exceeded this threshold value was considered anomalous. The Uranium count rate as shown in Figure 4 ranges from 1.69 to 6.21 ppm. Areas of localized high values greater than the threshold value of 5.092 ppm obtained from the statistical analysis (Table1) were noted around Akwana, Gboko and at the eastern part of Katsina-Ala. For Thorium, the count rate ranged from 6.79 to 27.71 ppm (Figure 5) while a threshold value of 20.78 ppm was obtained (Table 1). The southern portion of the study area was seen to have high concentration of Thorium. Figure 6 shows the Potassium count rate which ranges from 0.11 to 2.75%. Count rates greater than the threshold value of 1.5792% (Table 1) were dominant around Katsina-Ala and were considered anomalous. Parts of the study area that showed high concentration of the radionuclides (^{238}U, ^{232}Th and ^{40}K) could be associated with metamorphic rocks such as granites and gneiss while the part that showed low concentration of the nuclides could be associated with sedimentary rocks such as shale, clay and limestone[1,2,3].

The ternary map (Figure 7) shows the relative abundance of U, Th and K in the study area. The map shows that Thorium is most abundant in the study area, especially at the western and southern parts of the study area followed by Potassium which is especially seen at the central and northeastern part of the study area. Amongst the three radionuclides, Uranium concentration is relatively least abundant in the study area, although more at the centre of the study area near Akwana. The standard deviation of the concentrations of the radionuclides (Table 1) are all less than their mean activity concentrations, which indicates a high degree of uniformity.

The threshold value of the total count of the nuclides was statistically estimated at 41 cps. Areas such as Katsina-Ala and Akwana in which radiation concentration is greater than 41 cps, according to Uwah[7], are considered anomalous. The anomalies in these areas are significant for radioelement mineralization.

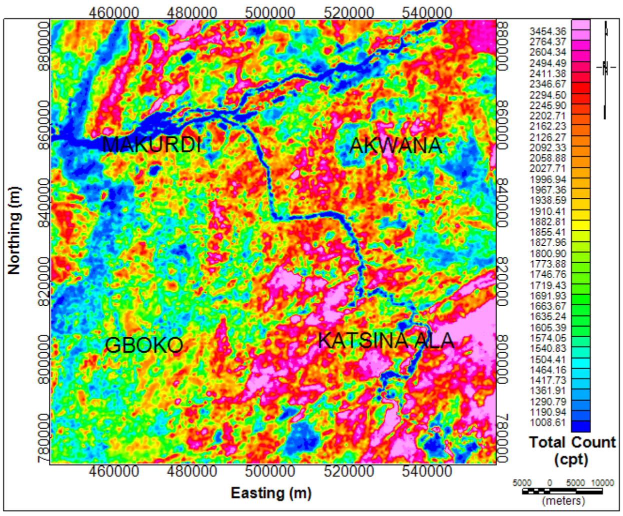

Figure 3. Total count rate of radioelements in the study area.

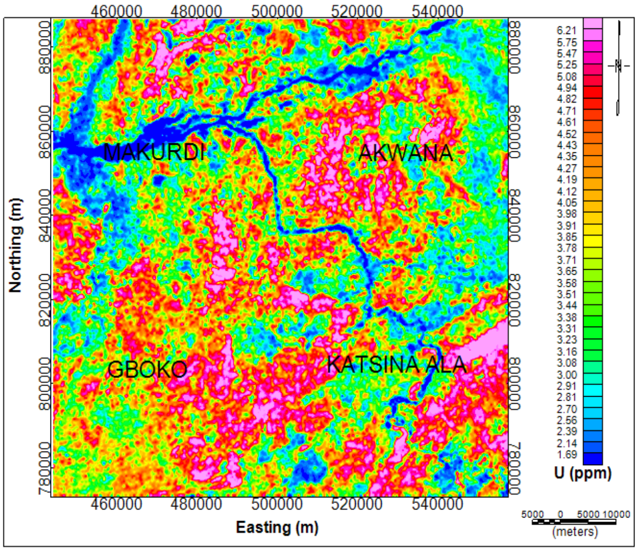

Figure 4. Distribution of Uranium in the study area.

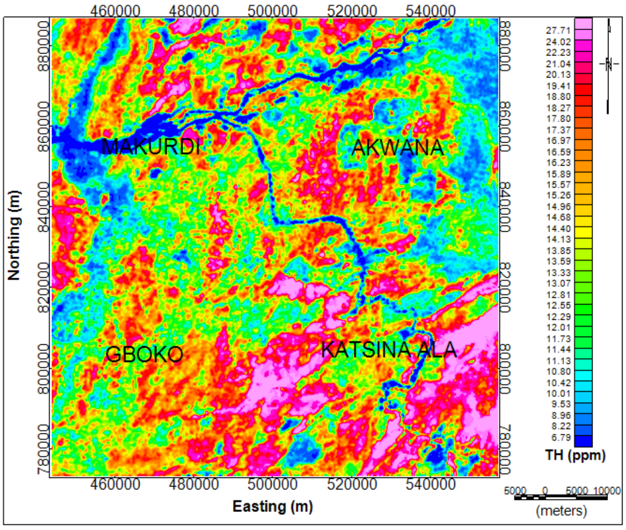

Figure 5. Distribution of Thorium in the study area.

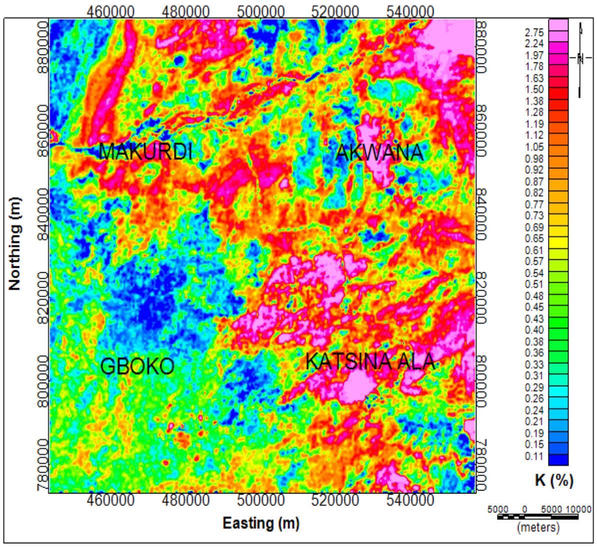

Figure 6. Distribution of Potassium in the study area.

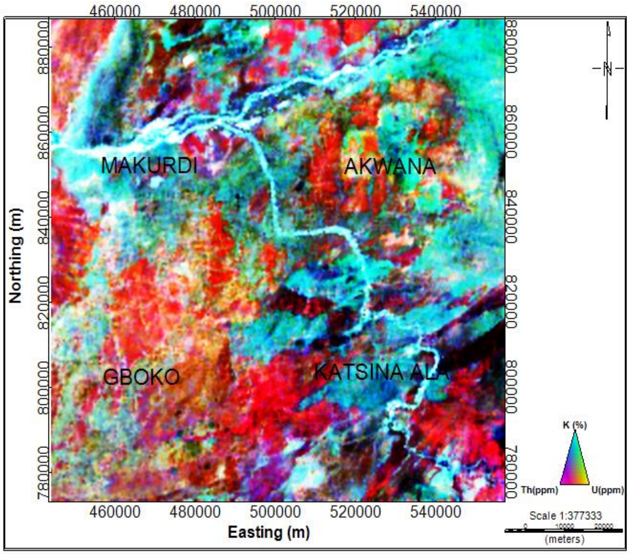

Figure 7. Ternary map of the study area.

Table 1: Summary of statistical analysis of the radiometric data.

S/N	Statistical Analysis	eU (ppm)	K (%)	eTh (ppm)	Total Count (cps)
1	Min	-1.23	-0.76	-4.32	-289.36
2	Max	13.45	5.49	78.24	7570.39
3	Mean	3.86	0.85	15.00	1912.07
4	Mode	3.61	0.33	12.44	1639.11
5	Std. Dev.	1.232	0.7292	5.78	570.3
6	Std. Error	0.005428	0.003212	0.02546	2.512
7	Median	3.80	0.61	14.22	1868.49
8	Skewness	0.3132	1.676	1.661	1.209
9	Kurtosis	1.534	3.239	7.957	6.886
10	Threshold value	5.092	1.5792	20.78	2482.37
11	EMA	4.842	1.0592	18.22	2209.41

IV. Conclusion

The interpretation of radiometric data over the study area revealed the concentration distribution pattern of the three primary radioelements: Potassium (K), Thorium (Th) and Uranium (U). The result obtained was used to delineate and characterize the mineralization at the study area. From the statistical analysis of the data and interpretation of the ternary maps, the most promising areas of Uranium mineralization were noted around Gboko and Katsina-Ala areas. The results also showed that the concentration of Potassium is highest around Katsina-Ala and at the northeastern borders of the study area while that of Thorium is highest around Katsina-Ala. The threshold value of the total count was statistically estimated at 41 cps. The approximate areas with sources of radiation which produce this anomaly (> 41 cps) are dominantly around Katsina-Ala area. Therefore the anomalies in these areas are significant in terms of radioelement mineralization.

Acknowledgement

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