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

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Abstract
Geophysical interpretation of airborne radiometric data over part of middle Benue trough of Nigeria for mineral deposits is here presented. High resolution airborne radiometric data of Wukari, Donga, Takum and Tissa areas bounded by latitude 7.0^0 *to* 8.0^0 *North and longitude* 9.5^0 *to* 10.5^0 *East were acquired from the Nigeria Geological Survey Agency (NGSA). The airborne radiometric data of the study area were interpreted quantitatively using the radiometric ratio and ternary radioelement signatures. Analysis of the radiometric data enabled determination of relative abundances of natural radioactive elements (Uranium, Thorium and Potassium). The count rate range of U (1.5 to 7.1 ppm), Th (6.2 to 40.3 ppm) and K (0.02 to 3.48 %) were observed within the study area. The ternary analysis revealed low concentrations of the three radioelements mainly at the northwestern Donga area. High concentrations of the three radioelements are predominant at the southern part of Donga area, trending towards the northeastern part of Takum area and are possible site for radiogenic heat exploration.From the qualitative analysis of the relative abundance of the radiometric elements and the ratio map analysis, rock bearing minerals such as limestone, sandstone, shale, gypsum, granite and minerals such as calcite, feldspar and quartz were identified, which could serve as raw materials for many industries in Nigeria.*

Key words*: Uranium, Thorium, Potassium, Radioelements, Radiometric ratio, Ternary map, Abundance.*

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I. Introduction

Airborne geophysical exploration is a method of geophysical survey adopted by earth scientists to survey very large unexplored, complex terrain or inaccessible regions of importance. This method is performed with the aid of fixed-wing aircrafts or helicopters or the use of space satellite. The technique can be used to reveal the different properties of bedrock or soils, from ground level down to numerous kilometers.

Airborne radiometric survey also known as Gamma-ray spectroscopy, measures the concentration of natural radiation in the earth's surface, which reveals the distribution of certain rock type formation. The method involves the measurement of naturally occurring radioactive elements that exists in rock forming minerals (Telford *et al.,* 1990; Wilford*et al.,* 1997; IAEA,2013) with a spectrometer attached to an aircraft which counts the number of times each gamma ray of particular energy intersects it.
This paper reports the result of the geophysical interpretation of aeroradiometric data over Wukari, Donga, Takum and Tissaareas of the Middle Benue Trough, Nigeria. It is believed that this project work will contribute to a better understanding of the mineral deposits in the area.

Geology of the Study Area

The study area has geographical coordinates of latitude 7.0^0 to 8.0^0 North and longitude 9.5^0 to 10.5^0 East in the Middle Benue trough. The Middle Benue Trough forms a link between the Upper and Lower Benue Trough (Figure. 1). The Middle Benue Trough passed through two major types of sedimentation cycles. The sedimentation in the Middle Benue area began in the Albian with the deposition of the Asu River Group whose age ranges from Middle Albian to Late Albian (Reyment, 1965; Offodile, 1976). The first sedimentary cycle deposited shales and limestones (Albian - Conomenian) along Wukari and Akwana. These sediments lie unconformably on the Precambrian basement rocks (biotite granites, hornblende gneiss). Along Makurdi areas,Turonian sandstones also overlie the basement directly. The second sedimentary cycles started from the Upper Conancian to late Maestrichtian depositing shales, limestones, sandstones and ironstone around Lafia, Agana and parts of Shendam. Other areas around Wamba, Akwanga,Shendam andLafiaare characterized by undifferentiated granites, migmatites, gneisses and tertiary – recent volcanic (Reyment, 1965; Offodile, 1976; Obi *et al.*, 2014). Figure 2 is the Stratigraphic succession map showing the Middle Benue Trough (Obaje, 2009).

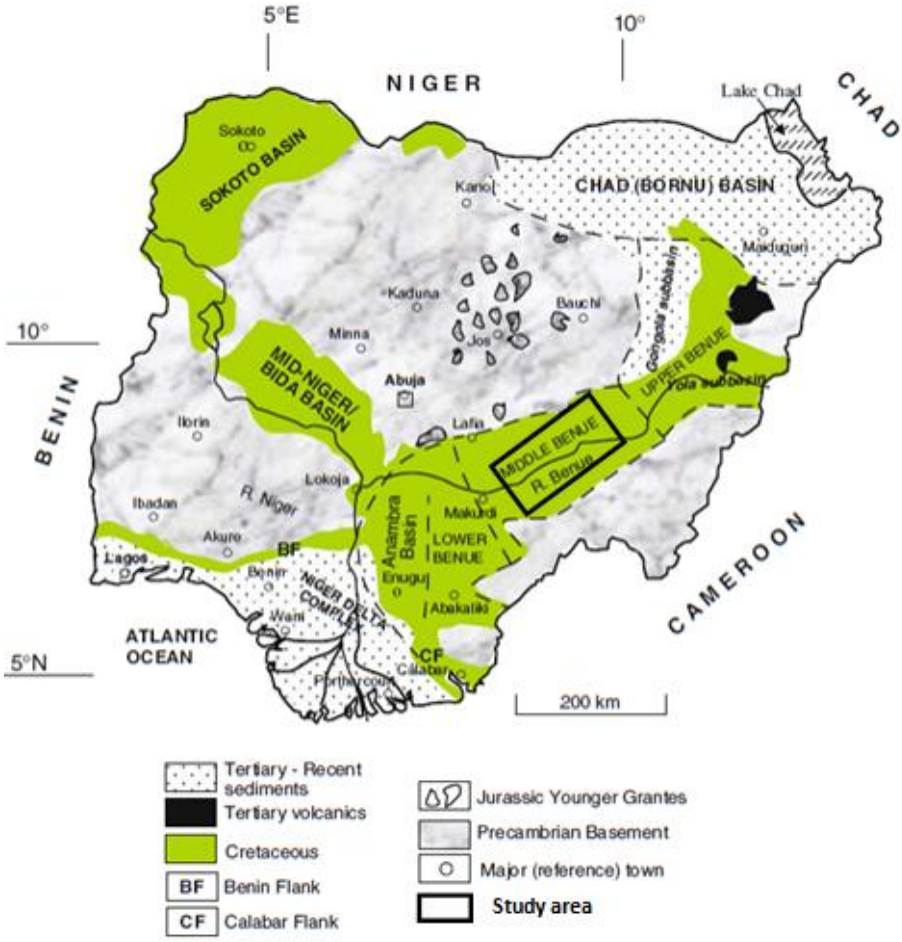

Figure. 1:Map of Nigeria showing the Middle Benue Trough (Obaje, 2009).

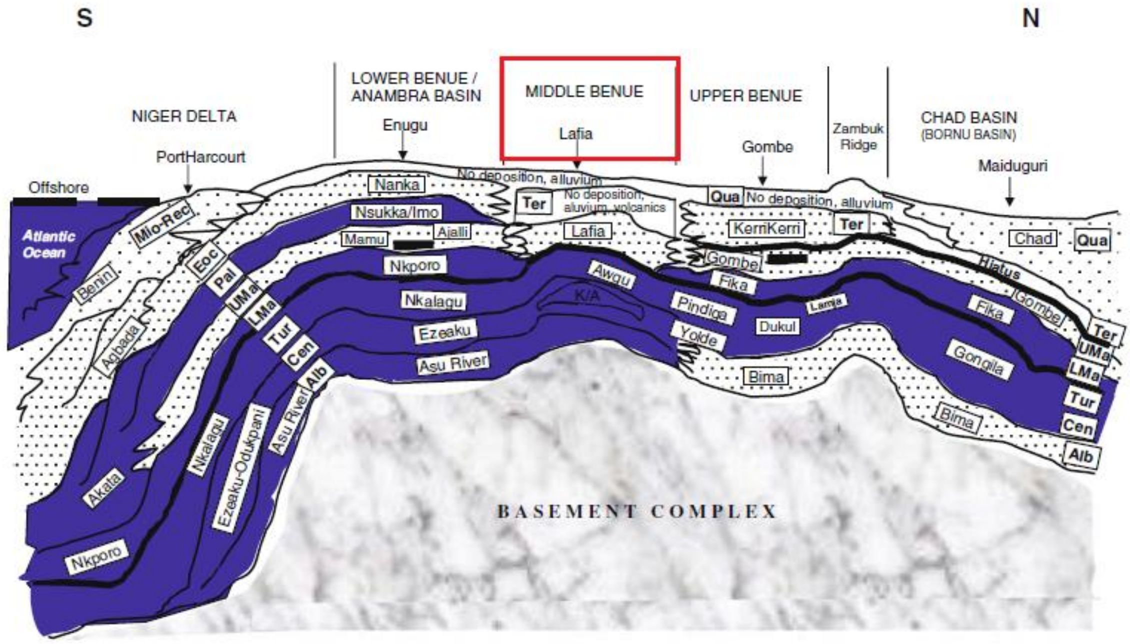

Figure. 2:Stratigraphic succession map showing the Middle Benue Trough (Obaje, 2009).

II. Materials and Method

Source of Data: The high resolution aeroradiometric data of Wukari (sheet 253), Donga (sheet 254), Takum (sheet 273) and Tissa (sheet 274) for this study were acquired from Nigerian Geological Survey Agency (NGSA) Abuja. The airborne survey was carried out by Fugro Airborne Survey between the years 2002 - 2009. The data obtained from the airborne survey was presented in digital form as a composite grid of 1:100,000 covering the study area. The aeroradiometric data were acquired at a flight elevation of 80 m, line spacing and tie-line spacing were 500 m and 5000 m respectively. A line direction of 135/315 degrees was accepted for the survey.

Data Analysis: The four data sheets obtained from NGSA were merged together. The merged data was imported into Oasis montaj8.4 software for the data analysis. The merging was done by combining the four different sheets into one single sheet , which forms the total area of study.The data is gridded to obtain the Potassium, Thorium, Uranium and Totalcount grid using the minimum curvature grid method.

Method

The map ratios of the radioelement were calculatedusing the grid ratio toolof the Oasis montaj 8.4 software. The ratios were calculated between the radioelement by assigning the values for the

$\frac{U}{Th}$

$\frac{U}{K}$ and$\frac{Th}{K}$

The ternary radioelement map presents a single display of the three radioelement concentrations showing areas of rich abundance and sparse abundance of the three radioelements(Telford *et al.,* 1990;Adonu*et al.,*2022).To produce the ternary map, the ternary analysis tool of the Oasis montaj 8.4 software was used in which standard colours such as blue, green and red were assigned to Uranium, Thorium and Potassium respectively.

III. Result and Discussion

The result obtained shows that the Uranium concentration ranges from 1.5 - 7.1 % (Figure. 3).

The high concentration zone which ranged from 6.3 to7.1 ppm (pink colour) is mainly in the southwest part of Donga area and northeast parts of Takum area. The low concentration zones are dominantly in northwestern part of Donga and southern part of Takum area and are likely attributed to sedimentary deposits such as limestone and sandstone containing calcite mineral when compared with the standard radioelements contents in various rock types by Galbraith and Saunders, 1983; Telford *et al.*, 1990.

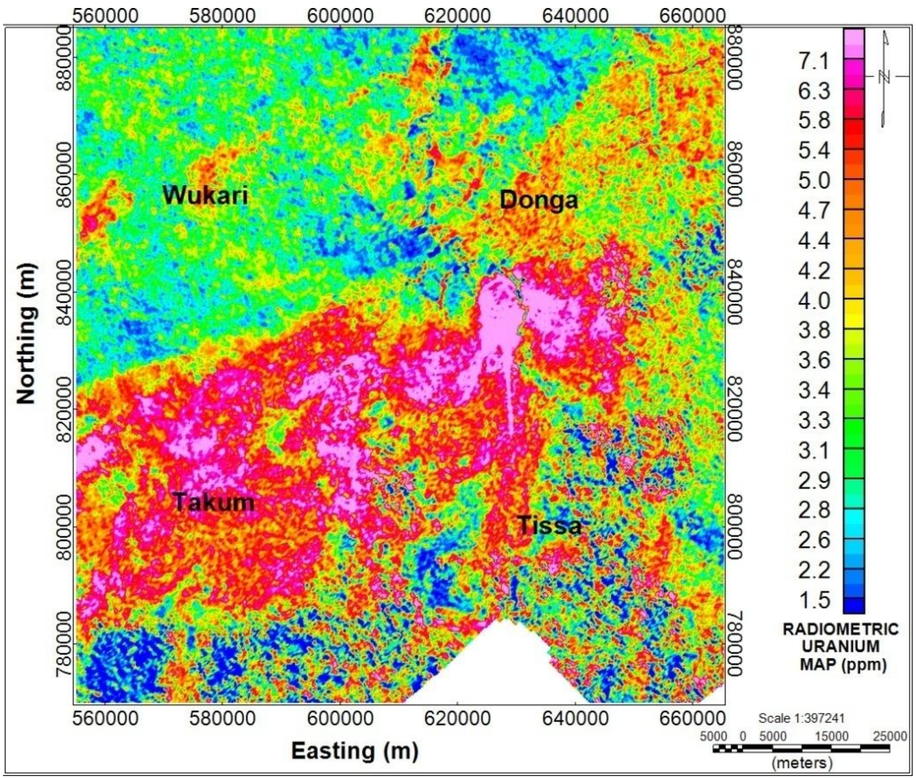

Figure.3: Geographic distribution of Uranium in the study area.

The concentration of K (Figure.4) revealed different degrees of potassium concentrations which reflect the lithology in the area. The Potassium concentration ranges from 0.02 to 3.48 %. The blue colour (0.02-0.18%) corresponds to low Potassium concentration. These are dominantly southwest of Takum and northwest of Donga area and are likely related to the presence of evaporite sedimentary deposits such as gypsum. The highest value (3.48 %) of K abundances are seen in Tissa area, southeastern Takum and southeastern Donga area, which when compared to the standard radioelements in various rock types may be attributed to the presence of felsic igneous deposist such as granite, feldspar and quartz minerals. (Galbraith and Saunders, 1983; Telford *et al*., 1990).

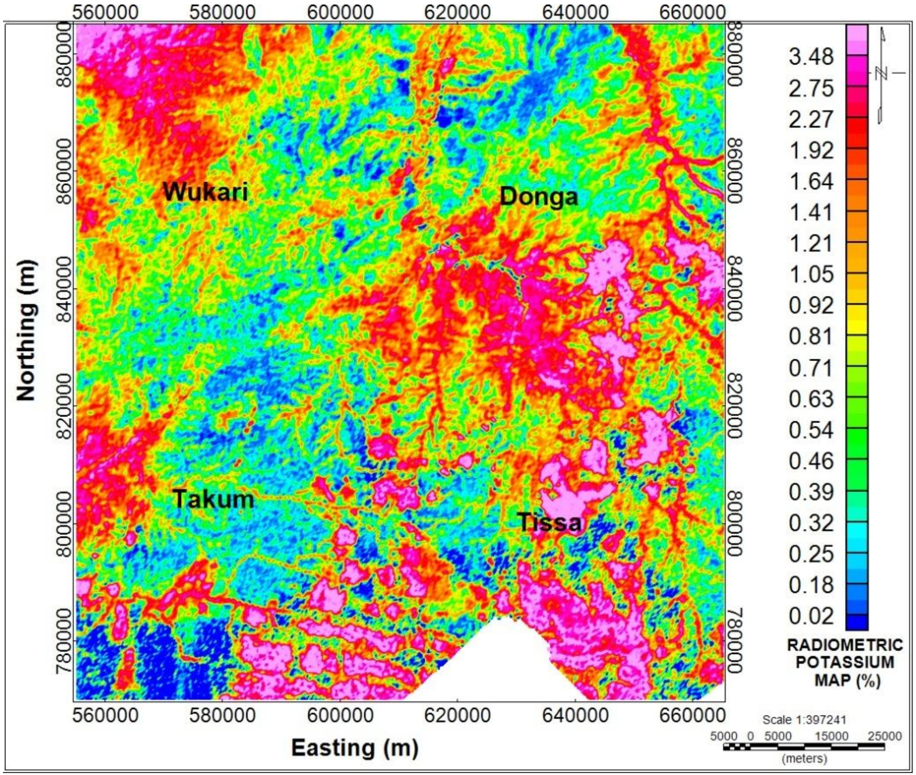

Figure.4: Geographic distribution of Potassium in the study area.

Figure 5 is the map of Th concentration of the study area. The Thorium abundances are in the range of 6.2 to 40.3 ppm. Low concentration of Thorium anomalies (blue colour) are mainly in northeastern part of Wukari, southwestern partof Donga and southern part of Takum and Tissaarea.High Thorium abundances at northeastern Takum to southern part of Donga area when compared with the standard radioelements contents in various rock types (Galbraith and Saunders, 1983; Telford *et al.* 1990) may be attributed to the presence of felsic igneous deposit such as granite containing feldspar mineral.

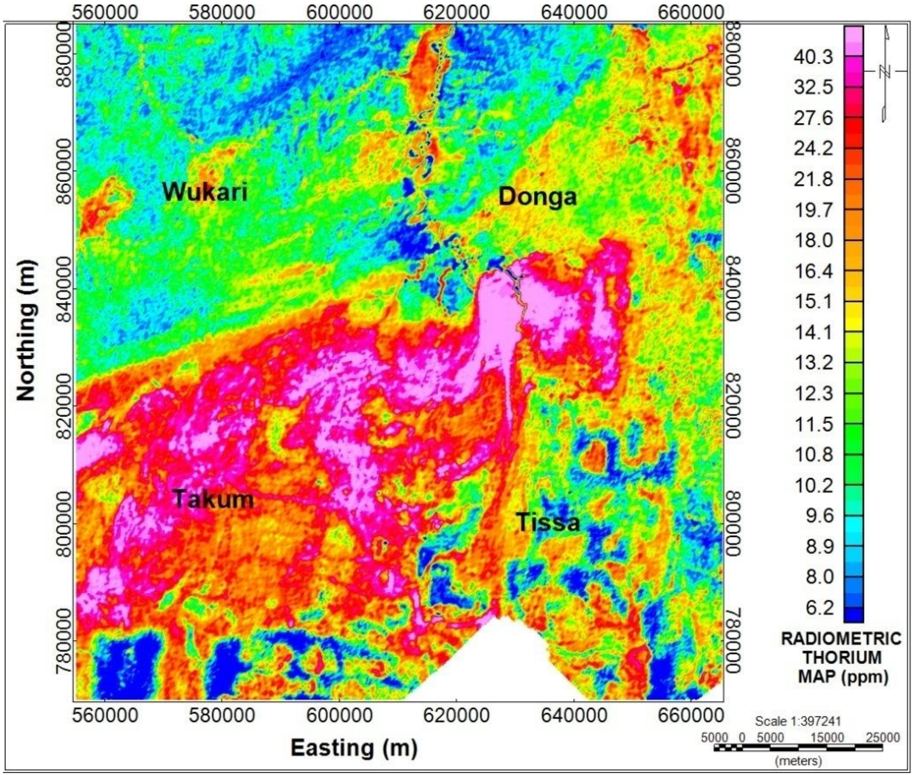

Figure.5: Geographic distribution of Thorium in the study area.

The total count map (Figure.6) brings out the combined effects of the three radioelements. The total count of the three radioelements (Uranium (ppm), Thorium (ppm) and Potassium (%)) ranges from 1035.1 – 4978.0 cpt. The map revealed that the three radioelements are more pronounced (pink and red colour) in the southern part of Donga area and Takum area while low concentration of total count rate was noted around the northwestern part of Donga area.

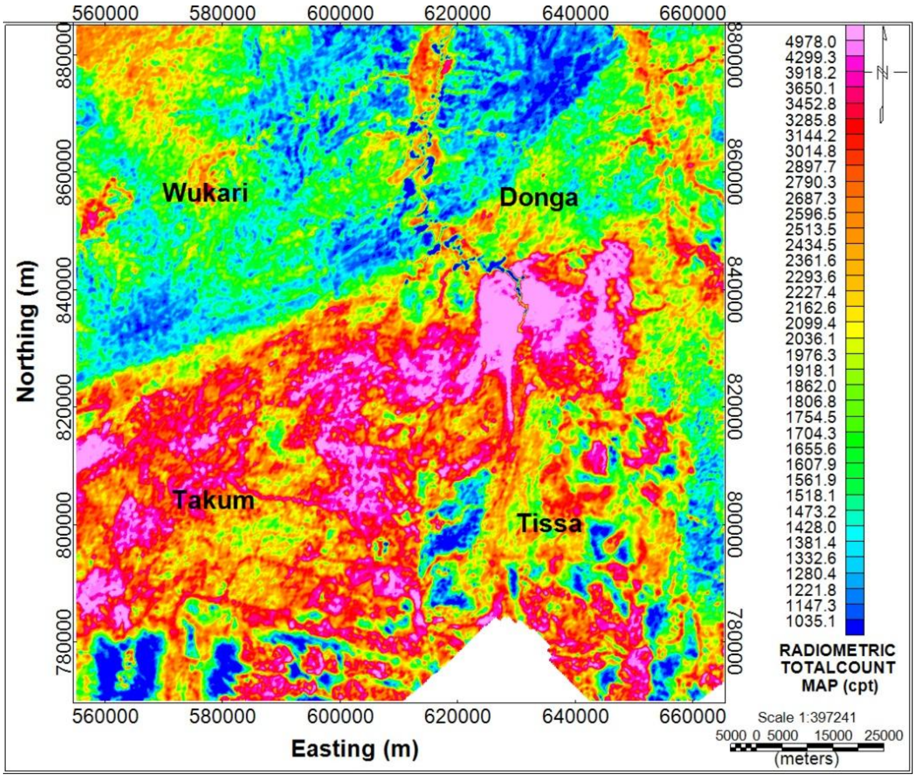

Figure.6: Total Airborne Radiometric Anomalies count map of the study area.

The Uranium to Thorium (U/Th) map (Figure.7) shows preferential Uranium toThorium in most parts of the study area. Enrichment of Uranium toThorium is observed dominantly (pink and red colour) in northernpart ofWukari. Through comparative assessment with the standard radioelements ratio in various rock types, the anomalies in the northern parts ofWukari may be attributed to sedimentary deposits such as shale and sandstones(Wilkes, 1981; Galbraith and Saunders, 1983; Telford *et al.* 1990; Shives*et al.*, 1995). The northwestern part of Wukari area with dominant enrichment of K may be good soil for agriculture (Wilkes, 1981).Figure 8 is the Uranium to Potassium (U/K) ratio map of the study area. The U/K ratio map reveals preferential enrichment of Uranium to Potassium which is predominant (Pink and red colour) in Takum area while Potassium enrichment is observed (blue colour) in most parts of the study area.U/K ratio map reveals preferential enrichment of uranium to potassium which is predominant in Takum area while potassium enrichment is observed in most part of the study area. Figure 9 is Thorium to Potassium (Th/K) ratio map of the study area. High Th/K ratio signatures are observed (pink and red) around Takum part of the study area while regions with low Th/K ratio indicate preferential enrichment of Potassium to Thorium which is observed (green colour) in northwestern part of Wukari and other parts of the study area.

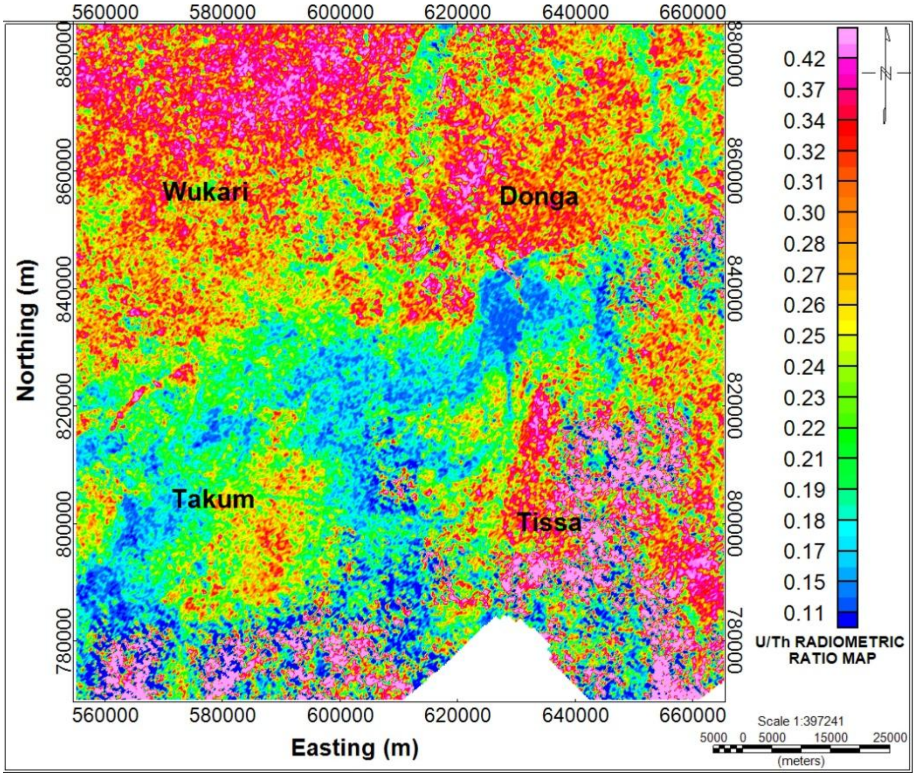

Figure.7: Uranium to Thorium (U/Th) ratio map of the study area

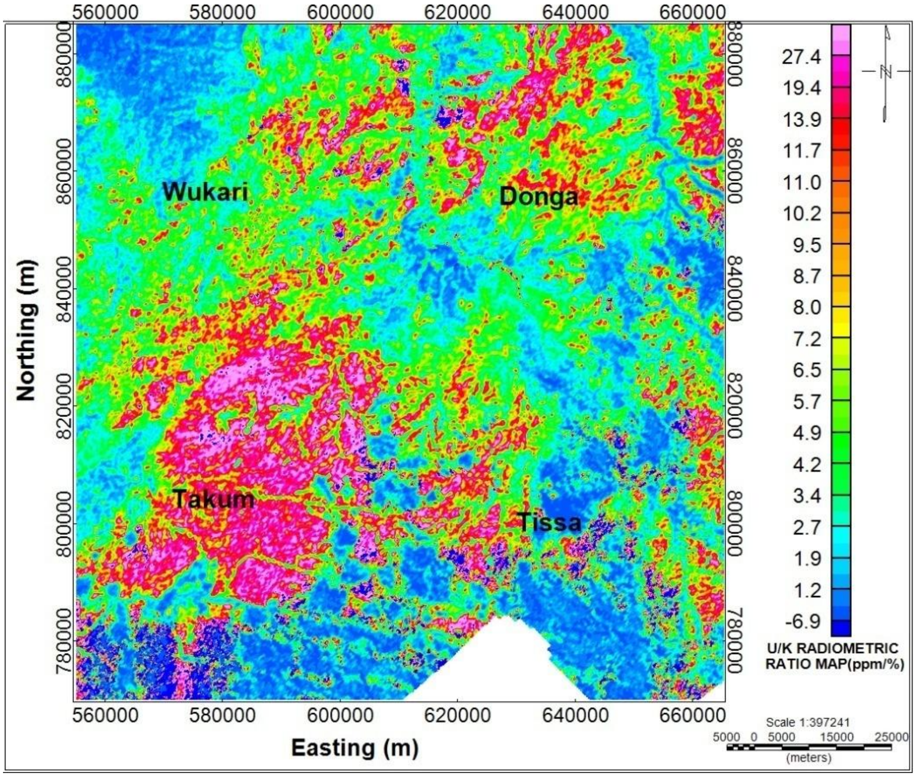

Figure.8: Uranium to Potassium (U/K) ratio map of the study area

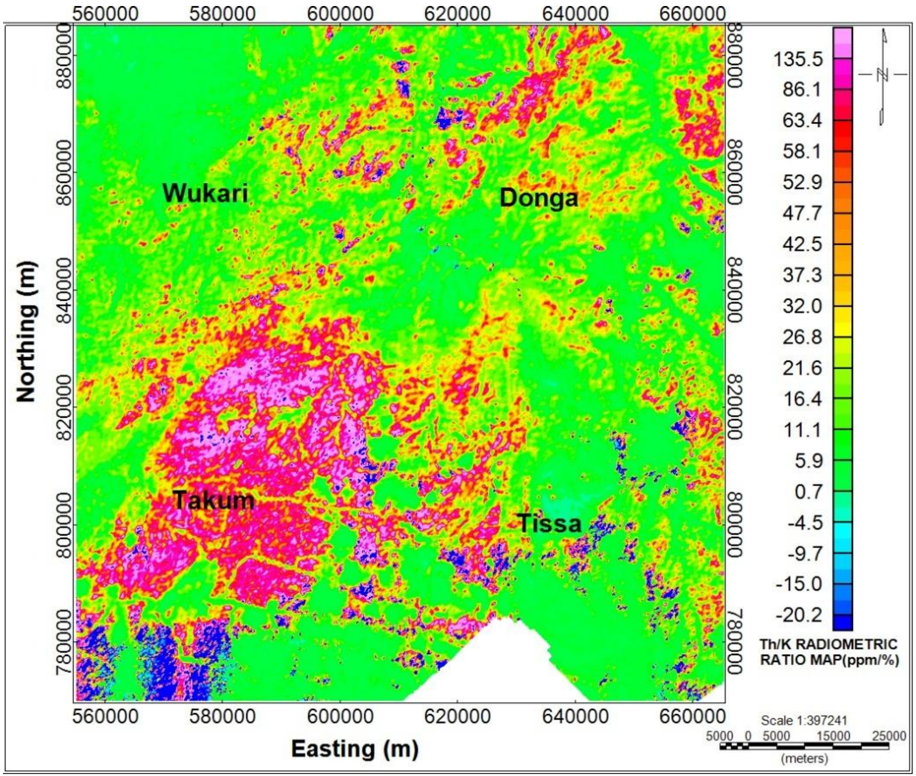

Figure.9: Thorium to Potassium (Th/K) ratio map of the study area

Ternary Map of the Study Area

The ternary map (Figure.10) display the combined intensities of U, Th and K in blue, green and red colours respectively. Low concentrations of the three radioelement are displayed in black colour which is denoted by (LC3R) and the white colour shows high concentrations of the three radioelement which is denoted by (HC3R). The LC3R is dominant in northwest part of Donga area. Similarly, the HC3R is predominant at the southern part of Donga area trending towards the northeastern part ofTakum area. The zones with dominant enrichment of K are seen in northwest part of Wukari area which may be good soil for agriculture.

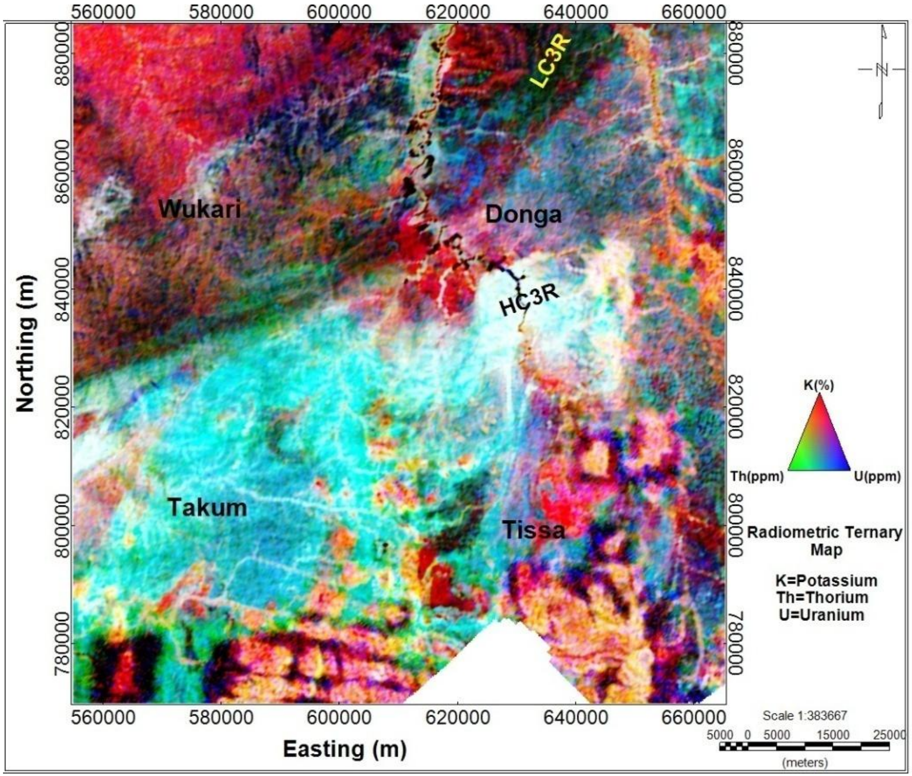

Figure.10: Ternary Map of the study area

IV. Conclusion

Analysis and interpretation of the radiometric data over part of the middle Benue Trough, Nigeria has enabled the determination of relative abundance of natural radioactive elements (Uranium, Thorium and Potassium). The triangular plot of the radioelements showed a ternary image by combining the three radio-elements U, Th and K. The southernpart of Donga area and the northeastern part of Takum areahas high concentrations of the three radioelements and are possible site for radioelement mineralization and radiogenic heat exploration. From the qualitative analysis of the relative abundance of the radiometric elements and the ratio map analysis, rock bearing minerals such as limestone, sandstone, shale, gypsum, granite and minerals such as calcite, feldspar and quartz were identified in the study area, which could serve as raw materials for many factories and industries in Nigeria.

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