African Journal of Environment and Natural Science Research
ISSN: 2689-9434
Volume 6, Issue 3, 2023 (pp. 132-142)
www.abjournals.org

INTERPRETATION OF HIGH-RESOLUTION AIRBORNE RADIOMETRIC DATA OVER PART OF LOWER BENUE TROUGH, NIGERIA

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Cite this article:

Okoro L.O., Ugwu G.Z., Onyishi G.E. (2023), Interpretation of High-Resolution Airborne Radiometric Data Over Part of Lower Benue Trough, Nigeria. African Journal of Environment and Natural Science Research 6(3), 132-142. DOI: 10.52589/AJENSR-CUAGW5MW

Manuscript History

Received: 28 May 2023

Accepted: 17 July 2023

Published: 9 Nov 2023

ABSTRACT: *Airborne radiometric data of part of Lower Benue Trough of Nigeria were interpreted quantitatively to determine the relative abundance of natural radioactive elements of Uranium (U), Thorium (Th) and Potassium (K) in the area. The observed count rate for Uranium, Thorium and Potassium in the study area were 0.8−6.8 ppm, 4.3−23.2 ppm and 0.09−0.63 % respectively. A ternary image of the radio-elements showed that the northern parts of Dekina and Soko have low concentrations of the three radionuclides whereas high concentration of the three radionuclides were noted at the northern part of Angba, southern part of Dekina and the western part of Ankpa. The ternary map also showed that Potassium in comparison to Uranium and Thorium in the study area is more abundant around the Angba area. The result of the radioelement maps and radiometric ratio maps revealed the presence of shale, feldspar, gabbro, granite and amphibolite in the study area. These mineral deposits could serve as raw materials for industries in Nigeria if harnessed.*

KEYWORDS: Mineralization, Radiometric Data, Radiometric Ratio, Relative Abundance, Ternary Image.

Article DOI: 10.52589/AJENSR-CUAGW5MW
DOI URL: https://doi.org/10.52589/AJENSR-CUAGW5MW

INTRODUCTION

Airborne radiometric survey has become increasingly popular in mineral explorations, especially in large exploration areas of complex terrain or inaccessible regions. This geophysical technique is used to estimate the concentration of radioelements in rocks by measuring the gamma rays emitted by the radioactive isotopes of these elements undergoing radioactive decay (Adonu *et al.*, 2022; Ani *et al.*, 2023; Ngwaka *et al.*, 2023). There are many naturally occurring elements possessing radioactive isotopes but only Uranium, Thorium and Potassium decay series have radioisotopes that produce gamma rays of sufficient energy and intensity which can be measured by gamma-ray spectrometry (Galbraith & Saunders, 1983). The gamma rays from the decaying unstable nuclei of the rocks are recorded during radiometric surveys. The radioelement composite image recorded therefore gives a single display of the three radioelement concentrations which reveal the distribution of certain rock bearing minerals of interest. The Uranium, Thorium, and Potassium maps show regions where the specific radioelement has high or low concentration.

This research is therefore aimed at delineating the radiometric mineralization at Dekina, Soko, Agana, Angba, Ankpa and Otukpo parts of the Lower Benue trough by a quantitative interpretation of their aero radiometric data.

Most of the geophysical works carried out in the basin employed airborne magnetic investigations for spectral depth or sedimentary thickness determinations (Igwesi & Umego, 2013; Ike *et al.*, 2017; Alasi *et al.*, 2017; Ugwu *et al*., 2018; Asielue *et al*., 2019; Okoro *et al*., 2021). Hence, an aeroradiometric investigation of the area is important in order to evaluate the mineralization in the area from the relative abundance of these three radionuclides of Uranium, Thorium and Potassium.

Geology of the Study Area

The area of study is located in the Lower Benue Trough of Nigeria (Fig. 1) within latitude 7.0^0 to 8.0^0 North and longitude 7.0^0 to 8.5^0 East, with an area of approximately $18{,}150\ km^2$. The geology of the Benue Trough of Nigeria has been well documented (Reyment, 1965; Murat, 1972; Nwachukwu, 1972; Ofoegbu, 1984; Ofoegbu, 1985; Obaje, 2009). The Benue Trough is underlain by a thick sedimentary sequence, deposited during the cretaceous time (Reyment, 1965). The depositional history of the Benue Trough is characterized by phases of marine regression and transgression (Reyment, 1965). The stratigraphic succession in the basin has been discussed by several authors (Reyment, 1965; Hoque, 1984; Ofoegbu, 1985; Obaje, 2009; Oweh, 2015). Fig. 1 is the stratigraphic succession in the Benue Trough (Obaje, 2009). The oldest sediment of the sequence belongs to the Asu River group which overlies the Precambrian basement (Hoque, 1984). The Asu River group comprises bluish black shale with a minor sandstone unit. The shale is typically fractured and weathered to needle-shaped bodies at the surface. Sandstone horizons are minor in the extreme south, but tend to increase northwards (Oweh *et al.,* 2015). Deposited on top of these Asu River group sediments are the upper cretaceous sediments, comprising mostly the Ezeaku shale (Obaje, 2009; Ugwu *et al*., 2013) which consists of nearly 100 cm thick flaggy calcareous shale, sandy or shaley limestone and calcareous sandstones (Reyment, 1965). The youngest unit of the sequence is the Nkporo shale which overlies the Ezeaku shale unconformably.

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It is Campanian-Maastrichtian in age and mainly marine in character, with intercalations of sandstone. Fig. 2 shows the geological map of the study area.

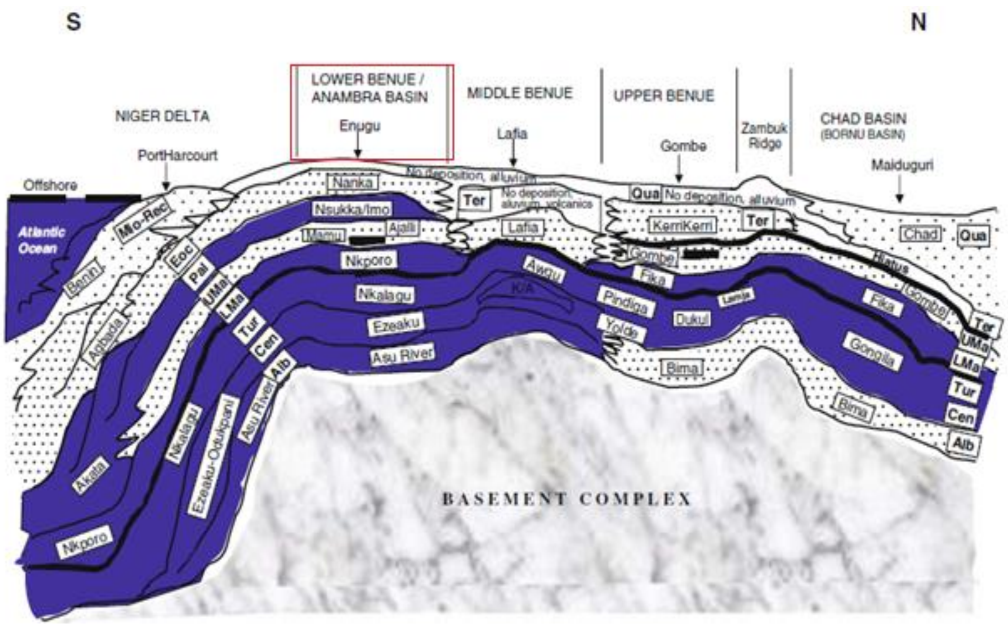

Fig. 1: Stratigraphic succession in the Benue Trough (Obaje, 2009)

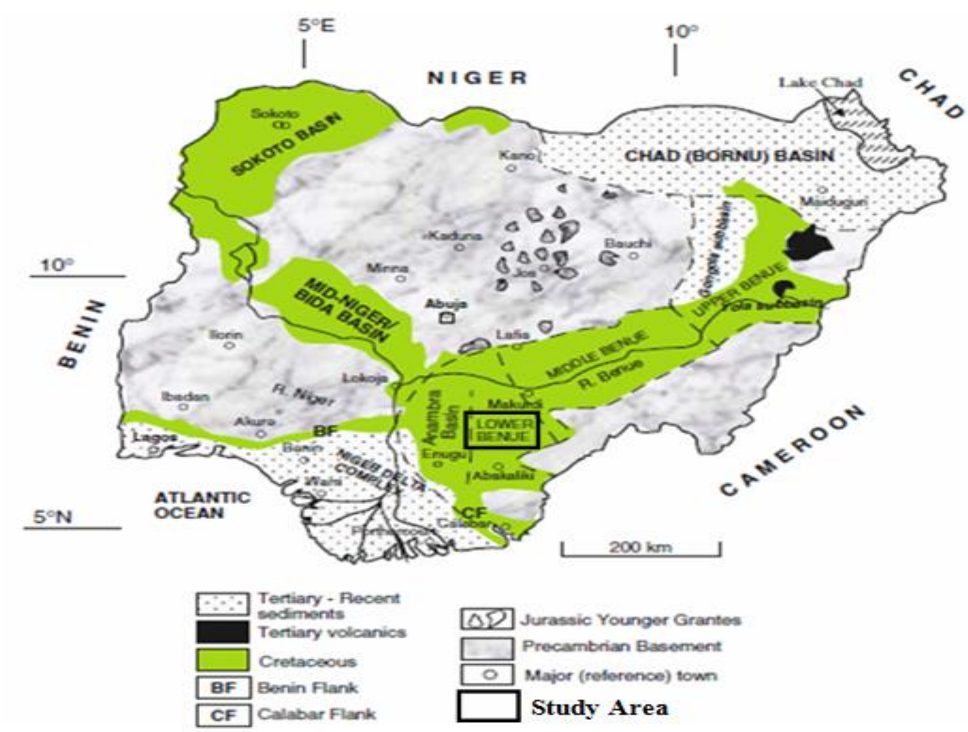

Fig. 2: Geological map of Nigeria showing the study area (Obaje, 2009)

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MATERIALS AND METHOD

Source of Data

The high resolution airborne radiometric data of Dekina (sheet 248), Soko (sheet 249), Agana (sheet 250), Angba (sheet 268), Ankpa (sheet 269) and Otukpo (sheet 270) for this study were acquired from Nigerian Geological Survey Agency (NGSA). The high resolution airborne radiometric survey was carried out by Fugro Airborne Survey between the years 2002 and 2009. The data obtained from the airborne survey were presented in digital form as a composite grid of 1:100,000 sheets covering the study area. The aeroradiometric data were acquired at a flight elevation of 80 m, flight line spacing of 500 m and tie-line spacing of 2000 m.

Method

The six sheets of the radiometric data were merged together to form a composite data sheet of 18,150 km^2 which forms the study area. The merged data were imported into Oasis Montaj 8.4 software for gridding using the minimum curvature tool to produce an enhanced radiometric distribution of the count rate of the three primary radioelements (Uranium, Thorium and Potassium).

The radiometric ratios of the three nuclides ($\frac{eU}{eTh}$, $\frac{eU}{K}$, and $\frac{eTh}{K}$) were calculated using the grid ratio tool of the Oasis Montaj software. Radiometric composite maps of Uranium, Thorium and Potassium were also generated from the radiometric ratios of the nuclides. The Potassium composite map was generated by combining the K map in red, $\frac{K}{eTh}$ map in green and $\frac{K}{eU}$ map in blue, while the equivalent Thorium composite map was generated by combing the eTh map in red, $\frac{eTh}{eU}$ map in green and the $\frac{eTh}{K}$ map in blue. To obtain the equivalent Uranium composite map, the eU map in red, $\frac{eU}{eTh}$ map in green and the $\frac{eU}{K}$ map in blue were combined. Finally, a radiometric ternary map which is the composite image of the three radiometric elements was produced by modulating the red, green and blue in proportion to the concentrations of the radioelements K, Th and U in the study area.

RESULTS AND DISCUSSION

Fig. 3 shows the total count rate of the three radioelements: Uranium (ppm), Thorium (ppm) and Potassium (%) with a total count of about 529.2–2530.3 cpt. The map shows high count rates, mostly around Soko and western Otukpo areas, whereas low count rates were recorded around Ankpa and Dekina areas. Fig. 4 is the map of Uranium concentrations in the area. Uranium abundance is within the range of 0.8−6.8 ppm, with the localized zones of relatively high values (6.1−6.8 ppm) seen around the Soko area and at the eastern part of Ankpa. Uranium abundance when compared with the standard radioelements contents in various rock types (Galbraith & Saunders, 1983; Telford *et al.*, 1990) shows that Uranium abundance value of 0.8–1.7 ppm suggests the presence of gabbro and feldspar, mainly at the southern part of Dekina and at Ankpa

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area. Uranium values of 3.7−3.9 ppm possibly relate to the presence of sedimentary rocks such as shale mainly given at southern Otukpo area whereas those with values of 4.1–4.8 at the southern part of Agana are possibly acidic igneous rocks such as granite. The map of Thorium concentration in the study area is shown in Fig. 5. The Thorium abundance is in the range of 4.3−23.2 ppm. Low values (blue colour) of Thorium abundance can be seen mostly around Angba, Ankpa and at the southern part of Dekina, whereas Soko area and the eastern part Ankpa have high values (red and pink colour) of Thorium abundance. Potassium (K) abundance ranges from 0.09−0.63% (Fig. 6). Low K abundance (blue colour) is observed around Ankpa area and at the northern part of Agana area while high K abundance (pink colour) is observed mainly around Soko area and at the northern part of Dekina. This possibly relates to the presence of metamorphic rocks such as amphibolite at these places.

Fig. 7 is the Uranium to Thorium ratio ($\frac{eU}{eTh}$) map of the study area. The map shows preferential enrichment of Uranium to Thorium dominantly at the western part of Otukpo and at the eastern part of Ankpa. The rocks in the Otukpo area were identified as sandstones and shale, which agrees with the geology of the Lower Benue Trough (Reyment, 1965; Ofoegbu, 1985; Obaje, 2009; Asielue *et al.*, 2019). Fig. 8 shows the Uranium to Potassium ratio ($\frac{eU}{K}$) map. There is preferential enrichment of Uranium to Potassium at the southwestern part of Angba and eastern part of Ankpa. Thorium to Potassium ratio ($\frac{eTh}{K}$) map of the study area is shown in Fig. 9 with high enrichment signature observed dominantly around the Angba area. Regions such as Dekina and Agana with low enrichment of Thorium to Potassium suggest preferential enrichment of Potassium to Thorium.

The ternary map (Fig. 10) shows the combined intensity of U, Th and K in blue, green and red colour respectively. The map shows that K is relatively more abundant in the Angba area in comparison to Uranium and Thorium. This indicates that the area possesses good soil for agriculture (Ani *et al.*, 2023). In areas such as Soko and the northeastern part of Ankpa where all the three radioelement concentrations are low, the ternary image appears black, while in areas such as the southwestern parts of Soko and Ankpa where all the three concentrations are high, the ternary map appears white. These areas with high concentrations of the three radioelements are possible sites for radioelement mineralization and radiogenic heat exploration.

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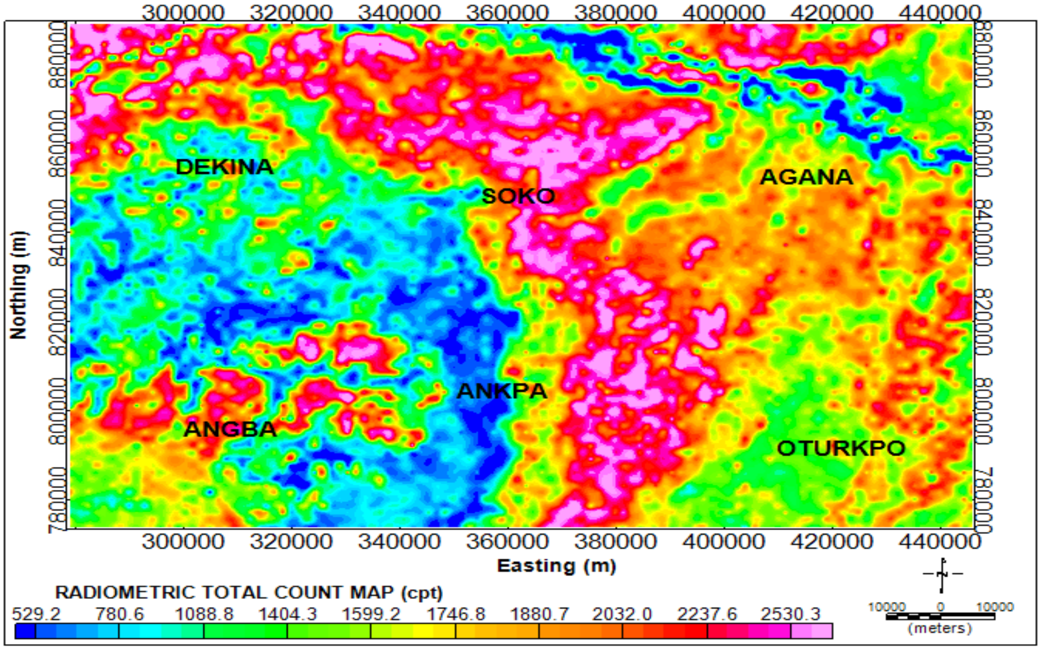

Fig. 3: Map of total radiometric count of the study area

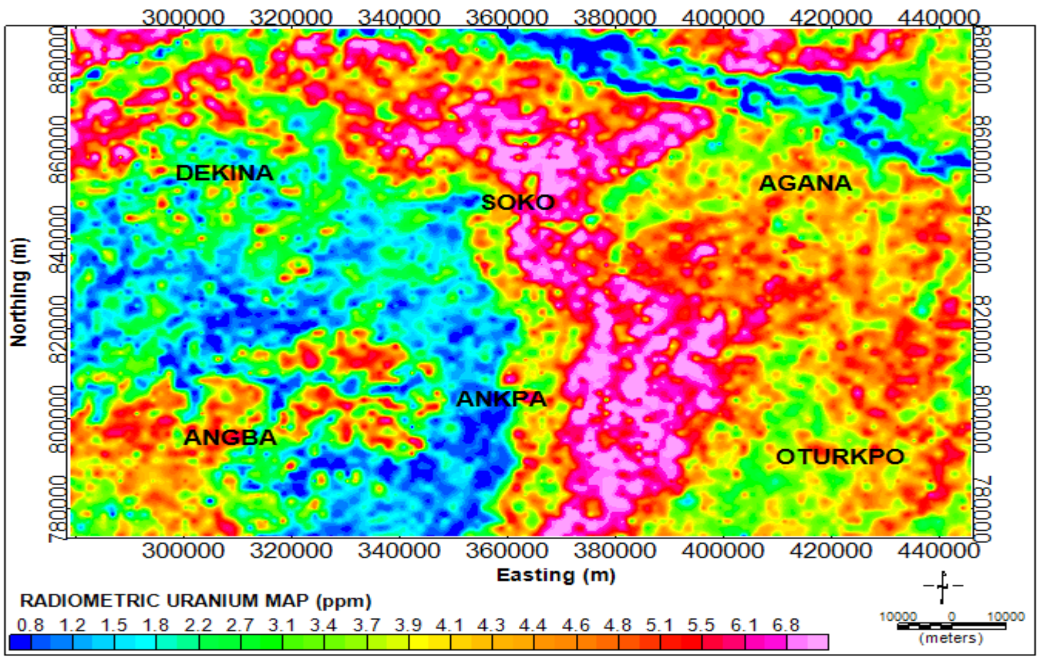

Fig. 4: Composite map of Uranium distribution in the study area

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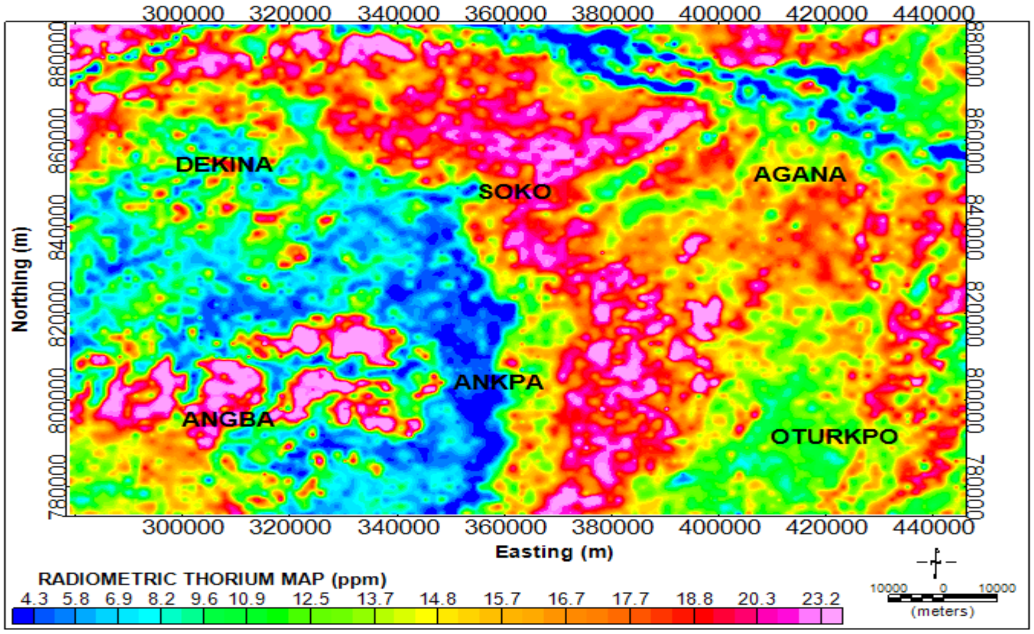

Fig. 5: Composite map of Thorium distribution in the study area

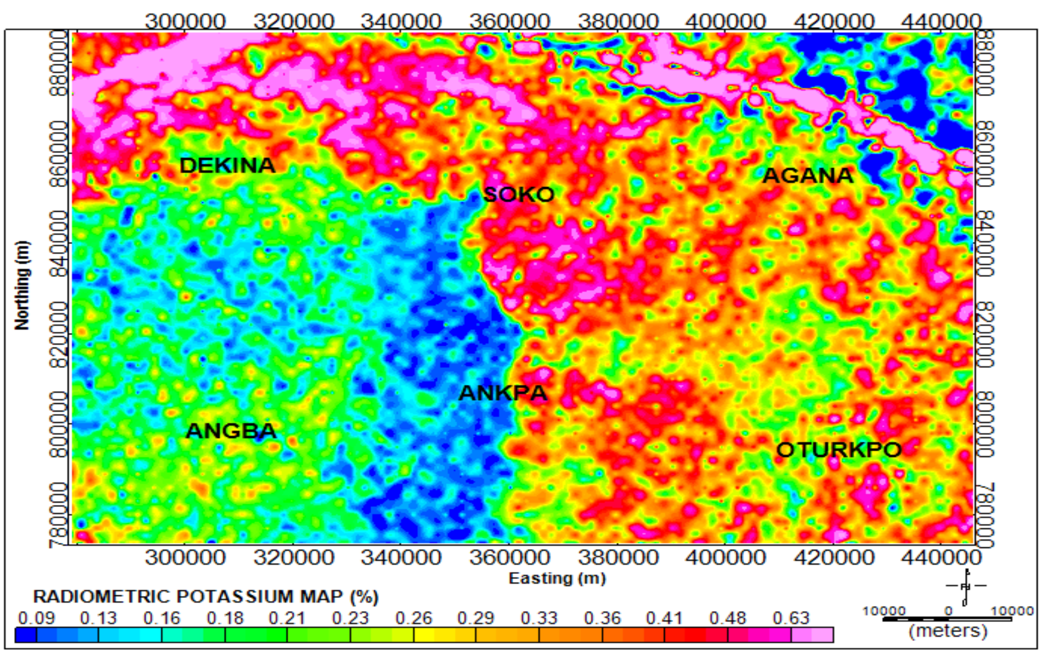

Fig. 6: Composite map of Potassium distribution in the study area

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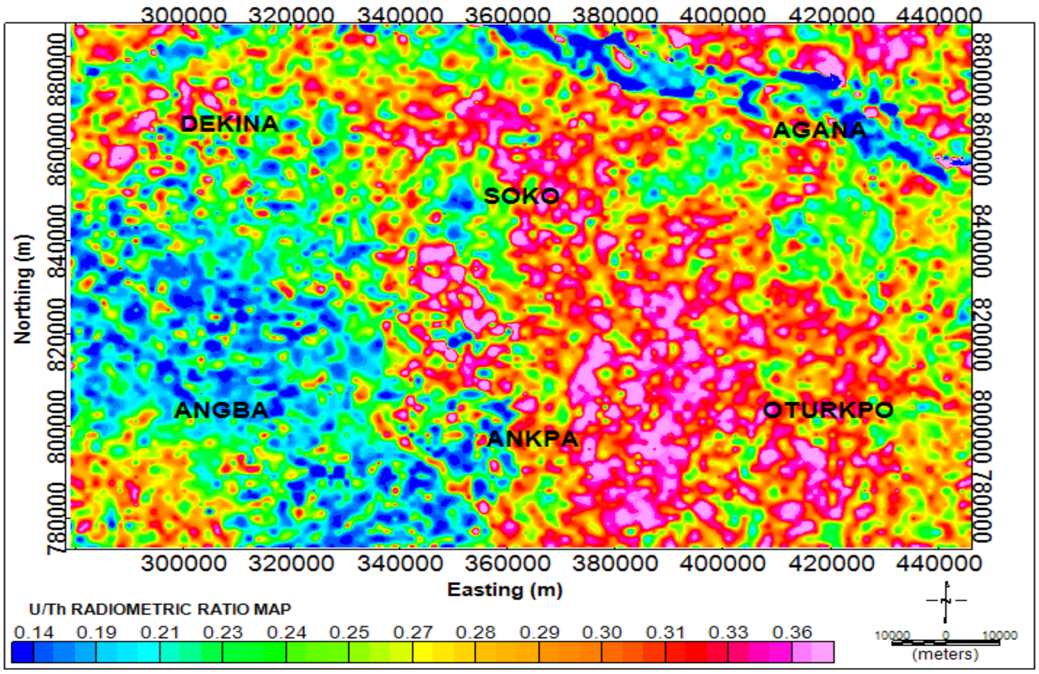

Fig. 7: Map of Uranium to Thorium ($\frac{eU}{eTh}$) ratio of the study area

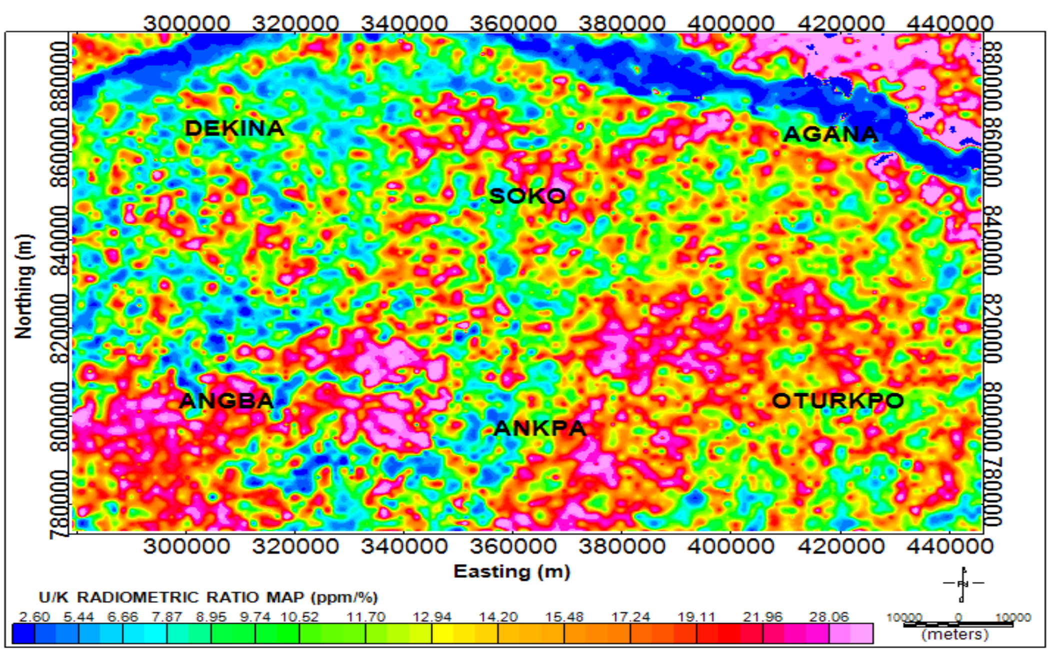

Fig. 8: Map of Uranium to Potassium ($\frac{eU}{K}$) ratio of the study area

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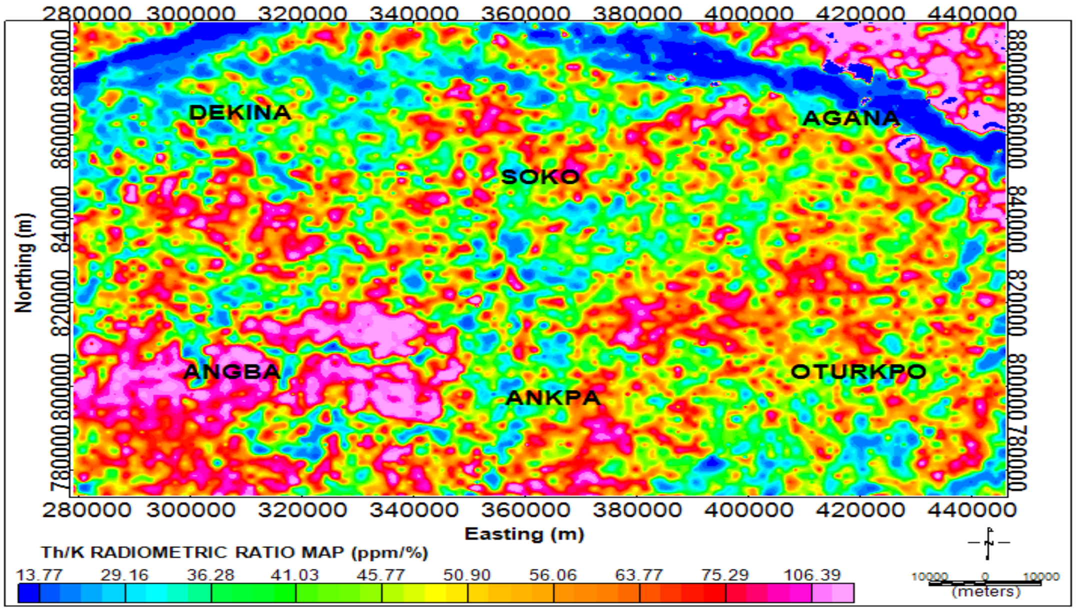

Fig. 9: Map of Thorium to Potassium ($\frac{eTh}{K}$) ratio of the study area

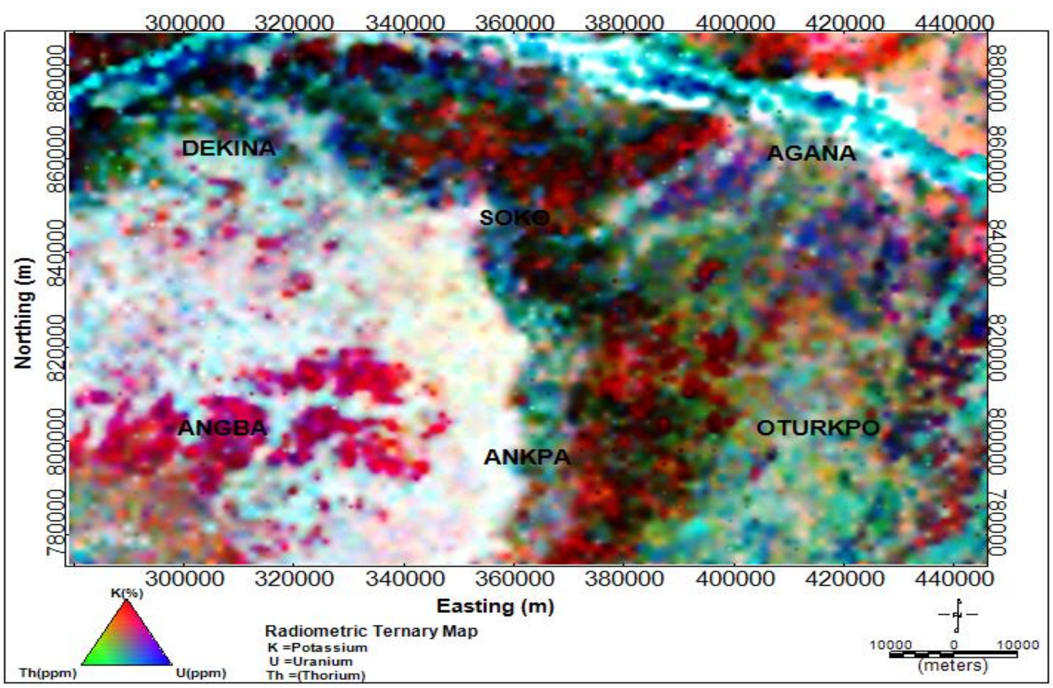

Fig. 10: Ternary map of the study area

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CONCLUSION

Aeroradiometric data of Dekina, Soko, Agana, Angba, Ankpa and Otukpo parts of the Lower Benue Trough of Nigeria have been interpreted quantitatively for solid minerals evaluation. The analysis of the radiometric data has allowed determination of relative abundances of the natural radioactive elements (Uranium, Thorium and Potassium) in rocks of this study area. The result of the radio elements maps and ratio maps analyses revealed the presence of some minerals and rock-bearing minerals such as shale, feldspar, gabbro, granite and amphibolite in the area. These mineral deposits, if harnessed, could serve as raw materials for many industries in Nigeria.

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