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Full Length Research

Investigation of relative abundance of radioelement concentration over a portion along Birnin Yauri, Northwestern Nigeria

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ABSTRACT: The radiometric method involves the measurement of naturally occurring radioactive materials emitting the ionization radiation (α, β, from rocks). In the field, the gamma rays and their adequate energies are detected by a spectrometer coupled with the scintillation detector. Three (3) high resolution airborne radiometric data obtained from the Nigerian geological survey agency (NGSA) were used to obtain the concentration of Potassium (K), Uranium (U) and Thorium (Th) respectively in the study area. The gridded data were fed into Oasis montaj software for appropriate filtering, in other to produce solutions for radioelement concentration across the area under study, thereafter producing shaded count maps as well as ternary maps. The result of the analysis revealed that potassium concentration is between 0.090 to 2.455% with an average of 2.365%. The thorium concentration values ranged from -0.539 to 15.221 ppm with an average of 7.341 ppm. The uranium concentration revealed values from -0.402ppm to 3.902ppm with an average of 1.75ppm. The ternary map of the radiometric data showed a red/cyan colour grid depicting potassium which is more pronounced across the area, followed by the uranium content(blue) covering an appreciable portion across with only but a few (green) coloured shaded regions depicting thorium. The results obtained have shown that the area has substantial amount of radioelement concentration, with potassium being the most abundant covering the central and western half of the area while the uranium content is more abundant towards the mid-western half and eastern parts of the area. The thorium content is minimal across the region.

Keywords: Birnin Yauri, potassium, radiometric data, radioelement, thorium, uranium.

INTRODUCTION

The radiometric method involves the measurement of naturally occurring radioactive materials emitting the ionization radiation (α, β, from rocks). In the field, the gamma rays and their adequate energies are detected by a spectrometer coupled with the scintillation detector. Theoretically, the energy of the gamma rays emitted from the natural radionuclides ranges from 0 to 3 MeV, but in the geological survey, the interest lies between 0.2 and 3 MeV. (IAEA, 2007). Peaks in the spectrum are attributed to potassium (%K), thorium (eTh) and uranium (eU), the count rate of the whole spectrum is referred to as the total count (TC) (IAEA, 2007). Such measurements indicate the radioactivity of layers from several cm up to 1.0 m depending on the measurement condition and geology.

The radiometric method is one of the most cost-effective and rapid techniques for geochemical mapping based on the distribution of the radioactive elements: potassium, uranium, and thorium. Nowadays, the method is mainly applied for geological mapping and exploration of other types of economic minerals; geochemical and environmental monitoring such as localization of radioactive contamination from the fallout of nuclear accidents and plumes from power plants; allowing the interpretation of regional features over large areas, and applicable in several fields of science (IAEA, 1991; 2007).

The little available information on uranium occurrences in Nigeria are mainly from individuals who have analyzed a few rock samples and uranium ores from some locations around the Nigerian younger granite province. However, the work of Uwah (1984), Dewu (1986), and Ahmed (1994) who carried out detailed investigation of radiometric anomalies in the Sokoto Basin, Bisichi and Jingir areas of Sokoto, and the plateau states respectively, form, a very important step for a large scale exploration of uranium and allied minerals. The rocks near the earth surface are often weathered. During weathering, thorium is often freed by the breakdown of minerals and may be remained in Fe or Ti oxides/hydroxides and with clays. Uranium is a reactive metal and is easily removed from its origin places. Some regions in Nigeria are rich in uranium such as Naraguta and Maijuju Sheets in Plateau State, Igabi, Kajuru, Kachia and Kalatu Sheets in Kaduna State as well as Ririwai in Kano State. All the mentioned places are within the ring complex belt of north-central Nigeria. Other areas that show significance uranium anomaly within Schist and Older Granites include Dangulbi and Kwiambana Sheets in Zamfara State, Kakuri and Bishini Sheets in Kaduna State as well as Igboho, Kishi, Meko, Abeokuta, Oyo, Kwara, Ogun, and Ikole Sheets (Arisekola and Ajenipa, 2013).

Further research work on the abundance of radioelement concentrations particularly uranium will go a long way to close the energy needs gap currently experienced in the country thus favourable for uranium project development and mining. The aim of this research work is to investigate the relative abundance of radioelement concentration over a portion along Birnin Yauri, Northwestern Nigeria using geophysical methods. This can be obtained by identifying the controlling geological processes influencing the concentration of radio nuclides in the rocks, which will aid in determining the abundance of radioelements concentration associated with different rocks in the area, and to also develop a ternary map showing the concentration of the radioelements in the area.

GEOLOGY OF THE AREA

The study area, Birnin Yauri located along Rijau road is in Ngaski Local Government area of Kebbi State, Northwestern Nigeria. The area is predominantly a gently undulating plain with an average elevation varying from 250 to 400 m above sea level. The location of the area is between latitude 10°30' to 11°00' N and longitude 4°00' to 04° 30' E. The plan is occasionally interrupted by low mesas and other escarpment feature, which is part of the Sokoto Basin of the Nigeria sector of the larger Iullumeden Basin; as illustrated in Figures 1 and 2. The Iullumeden Basin itself is a broader sedimentary basin covering most parts of Algeria, Niger Republic, Benin Republic, Mali, and Libya.

The general geology of the study area is dominated by two formations, the Precambrian Basement complex in the south to southeast and young sedimentary rocks in the North. The basement complex region is composed of very old volcanic and metamorphic rocks such as granites, schist, gneisses, and quartzite consisting of Gwandu, Illo and Rima groups whose ages range from cretaceous to the Eocene. The Gwandu group consists of clay massive interbedded with sandstone while Illo and Rima groups consist of pebbly grits, sandstones and clays, mudstones and siltstones respectively. Minerals that can be found in the area include quarts, Kaolin, photolytic bauxite, clay, potassium, silica sand, and salt (Adelana et al. 2008). This area is believed to be made up of both rocks of sedimentary terrain and that of the basement complex terrain with mostly clay, granites and pebble beds, feldspathic sandstones and siltstones, quartz, granite and migmatite.

MATERIALS AND METHODS

The materials required for this work include airborne radiometric data, a personal computer system, Math lab, Geosoft oasis Montaj and Golden software (surfer).

Airborne radiometric data

Nigerian Geological Survey Agency (NGSA) carried out an airborne survey over the study area with a gamma spectrometer. The radiometric data sets used were obtained at a flight line separation of 200 to 500 m flown at a planned terrain clearance of 120 m. The radiometric data were acquired with a high-sensitivity 256 channel airborne gamma spectrometer (AGRS) system comprising 32l of downward-looking NaI (Tl) (Sodium Iodide crystals treated with thallium) detector and 8l of upward-looking detector. Uranium (238U) is estimated through the radon daughter 214Bi in its decay chain, while thorium (232Th) is estimated through 208Tl in its decay chain. Potassium is measured directly at 1.461 MeV. The Potassium value was recorded directly in per cent (%) while the equivalent value of thorium (eTh) and uranium (eU) were obtained in part per million (ppm).

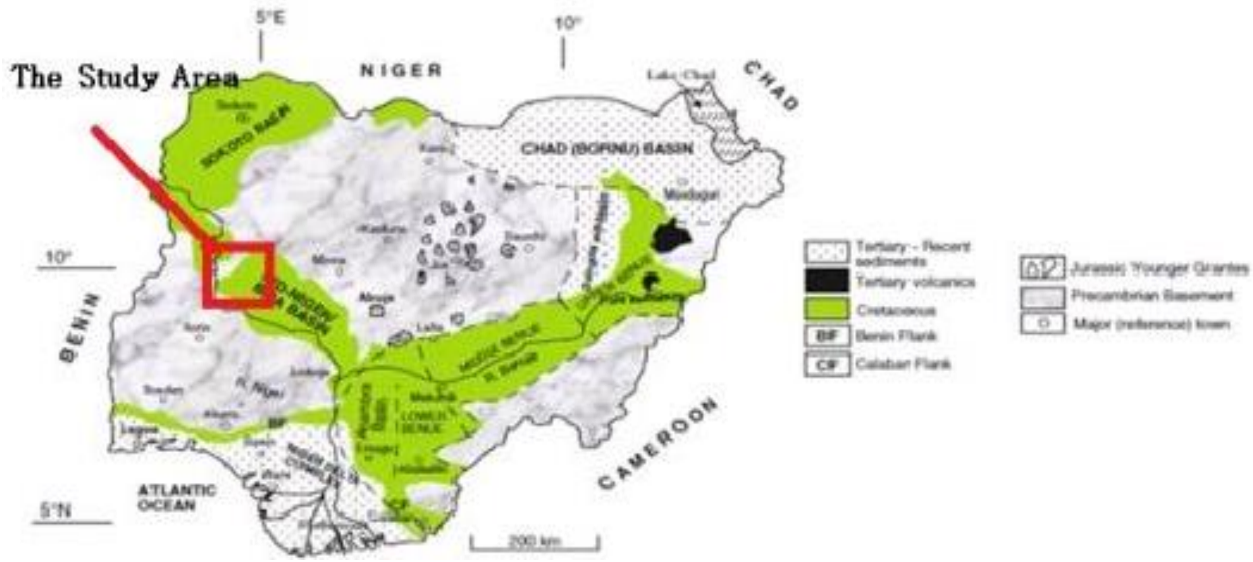

Figure 1. Location map of the Sokoto Basin.

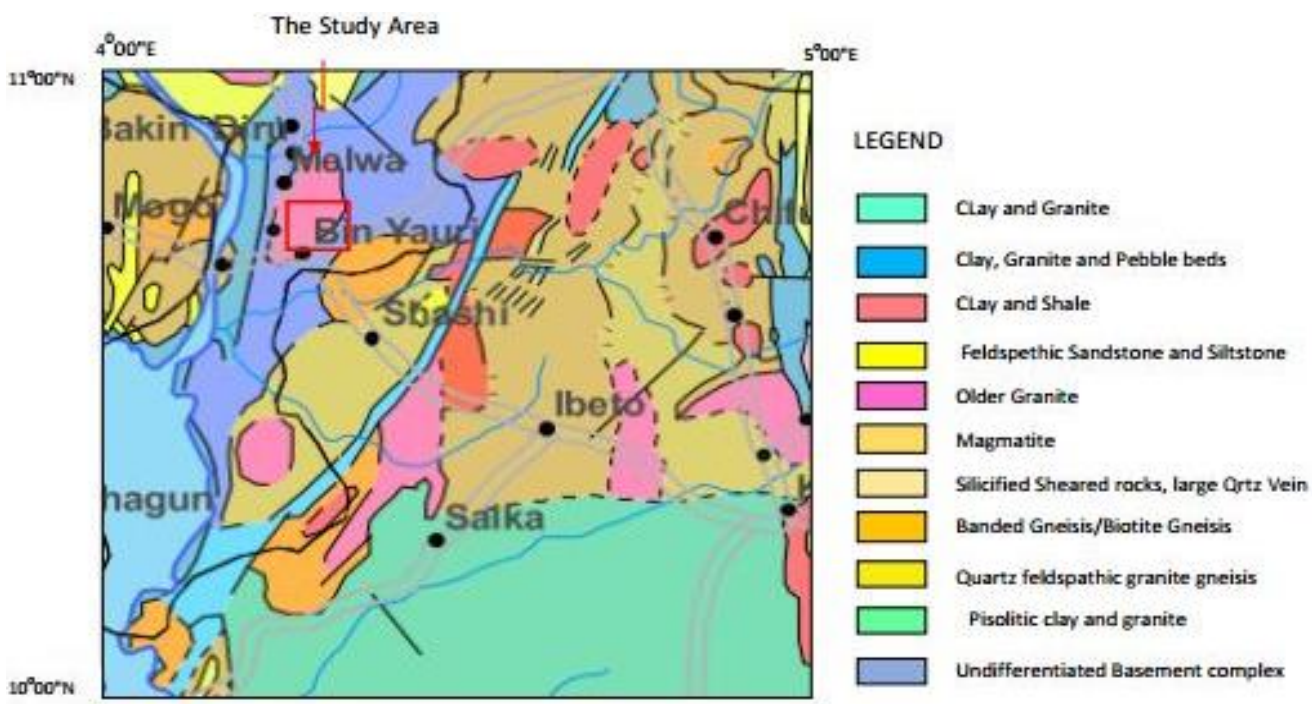

Figure 2. Geological map of the study area.

Survey methodology

Airborne geophysical surveys are normally flown on a regular grid along parallel lines ("flight lines"). The flight line spacing depends on the survey application. For detailed surveys, used for geological and environmental mapping, flight lines are usually between 50 and 400 m apart. Regional geochemical baseline surveys may be flown with a flight line spacing of 1 km or greater.

Surveys are typically flown at a constant height above the ground of between 40 and 100 m, with helicopters able to fly considerably lower than most fixed-wing aircraft. This is the “nominal” height of the aircraft above the ground, and the extent to which the aircraft deviates from this height depends on both the topography and the skill of the pilot.

Calculation of ratios for radioelement abundance

The ratios of the three radioelements (eU/eTh, eU/K, and eTh/K) are frequently plotted as profiles or contour maps. Due to statistical uncertainties in the individual radioelement measurements, care should be taken in the calculation of these ratios. The acceptable method of determining ratios is as follows:

1. Typically, neglect any data points where the potassium concentration is <0.25% as these measurements are likely to be over water.
2. Progressively, sum the element concentrations of adjacent points on either side of the data point until the total accumulated concentrations of both numerator and denominator exceed a threshold value. This threshold is normally set to be equivalent to at least 100 counts for both the numerator and denominator. This threshold will be obtained from the experimentally determined sensitivities.
3. Calculate the ratios using the accumulated sums. With this method, the errors associated with the calculated ratios will be similar for all data points.

Ternary radioelement map

A ternary radioelement map is a colour composite image generated by modulating the red, green and blue colours of the display device or yellow, magenta and cyan dyes of a printer in proportion to the radioelement concentration values of the K, Th, U and TC grids. The use of red, green and blue for K, Th and U, respectively, is standard for displaying gamma ray spectrometric data. Blue is used to display the U channel. Areas of low radioactivity, and consequently low signal-to-noise ratios, can be masked by setting a threshold on the total count grid. This reserves more colour space and ensures a better colour enhancement for the remaining data. Since this is the noisiest channel and the human eye is least sensitive to variations in blue intensity. The red colour is used to K channel while the green colour is used to display the Th channel.

Data analysis

The distributions of the three natural radionuclides (equivalent concentrations of thorium (eTh), equivalent concentrations of uranium (eU) and equivalent concentrations of potassium (K)) present in the study area have been obtained using the surveyed radiometric data (Figures 3 to 8, respectively). When weathering occurs, it modifies the distribution and the concentrations of radioelement when compared to the original bedrock. These gamma rays emitted from the surface are related to the weathered materials and geochemistry as well as the mineralogy of the bedrock.

RESULTS AND DISCUSSION

The map (Figure 3) shows the shaded thorium count map with the activity concentration of 0.589 to 15.221 ppm with major anomalous thorium count evenly distributed across the surveyed area. These values obtained correlate with the findings of Ahmed (1994), which indicates the sparse distribution of the major anomaly, the potassium count.

The map (Figure 4) represents a variogram depicting the concentration of the equivalent thorium concentration (eTh) in ppm with radioelement abundance of thorium prominently found along the eastern and western half with concentrations ranging from -10 to 125. This in other words shows that the rocks near the earth’s surface along the eastern and western half are often weathered as illustrated in Figure 4.

The map (Figure 5) shows the shaded uranium count map with activity concentrations of 0.402 to 3.902 ppm with major anomalous uranium count evenly distributed across the surveyed area.

The map (Figure 6) represents a variogram depicting the abundance of the equivalent uranium concentration (eU) in ppm with radioelement abundance of uranium prominently found within the western and central half with concentrations ranging from -1 to 17.

The map (Figure 7) shows the shaded potassium count map with activity concentrations of 0.090 to 2.455 per cent. With major anomalous potassium concentration evenly distributed throughout the region. It is the most abundant radioelement across the surveyed region.

The map (Figure 8) represents a variogram depicting the abundance of the equivalent potassium concentration (eK) in percentage with radioelement abundance of potassium present in almost all parts of the region evenly distributed.

Radioelements concentration map

The map (Figure 9) shows a ternary radioelement concentration map from a high-resolution gamma ray spectrometry survey acquired over a portion along Birnin Yauri, Northwestern Nigeria.

From the result obtained (Figure 9), the red/cyon colour grid depicting potassium that was supposed to be more pronounced is being superimposed by the uranium content (blue) with only but a few (green) depicting thorium. The eastern and western flanks of the study area are regions

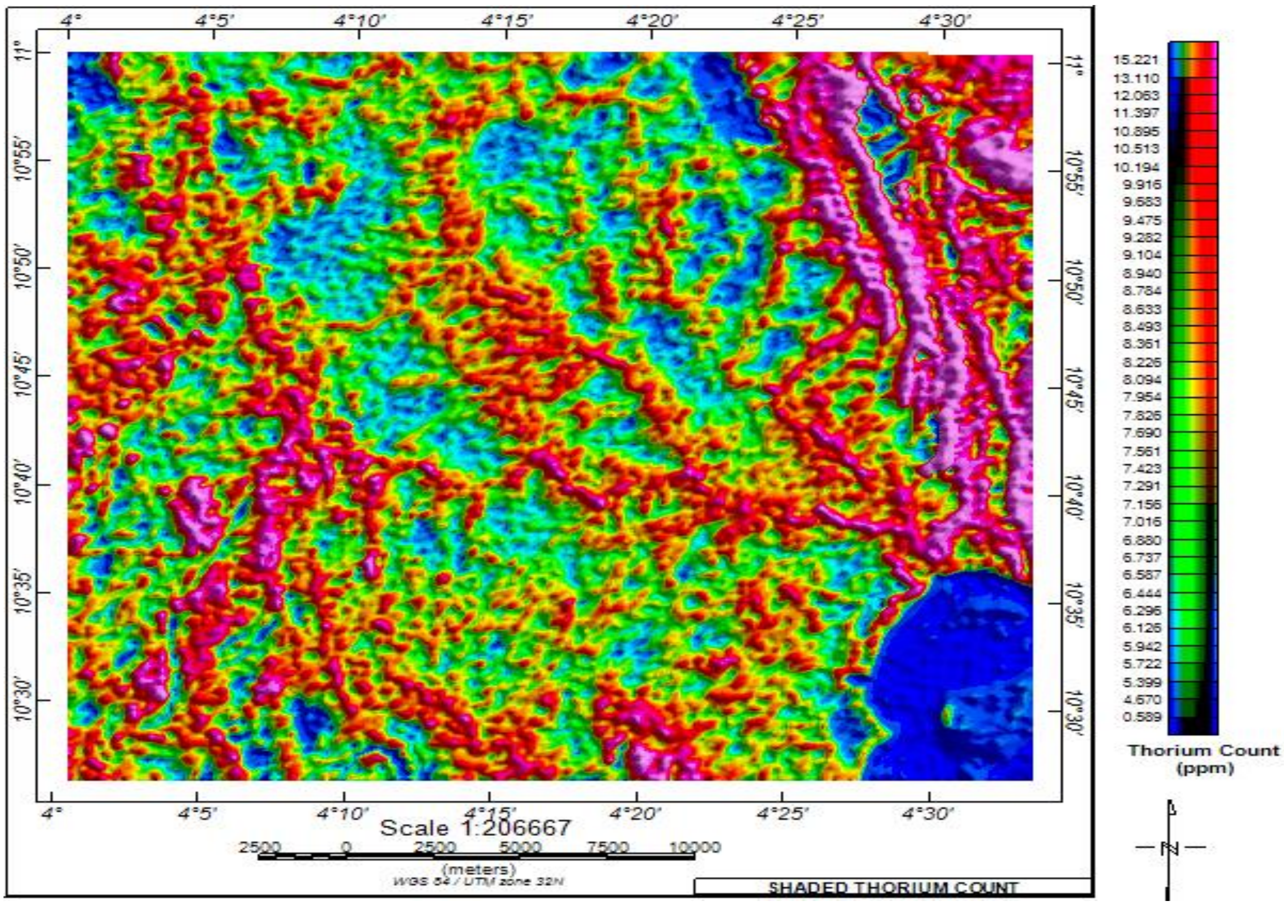

Figure 3. Shaded thorium count map of the study area.

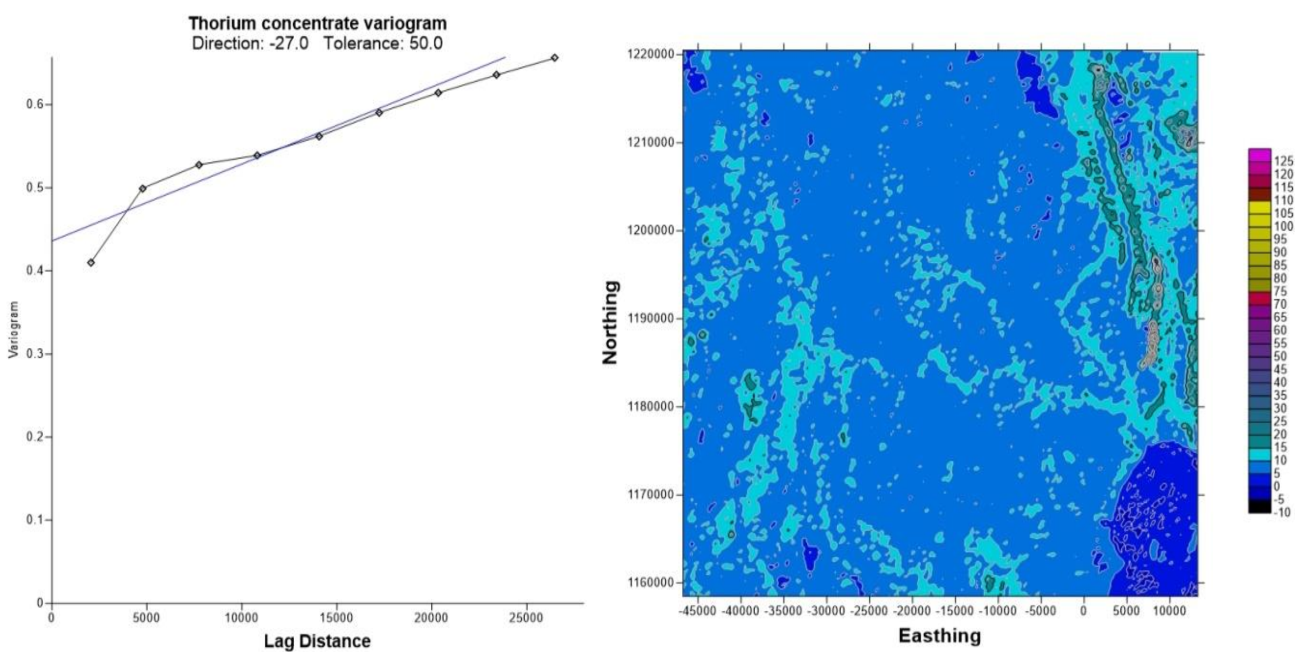

Figure 4. Thorium concentration variogram.

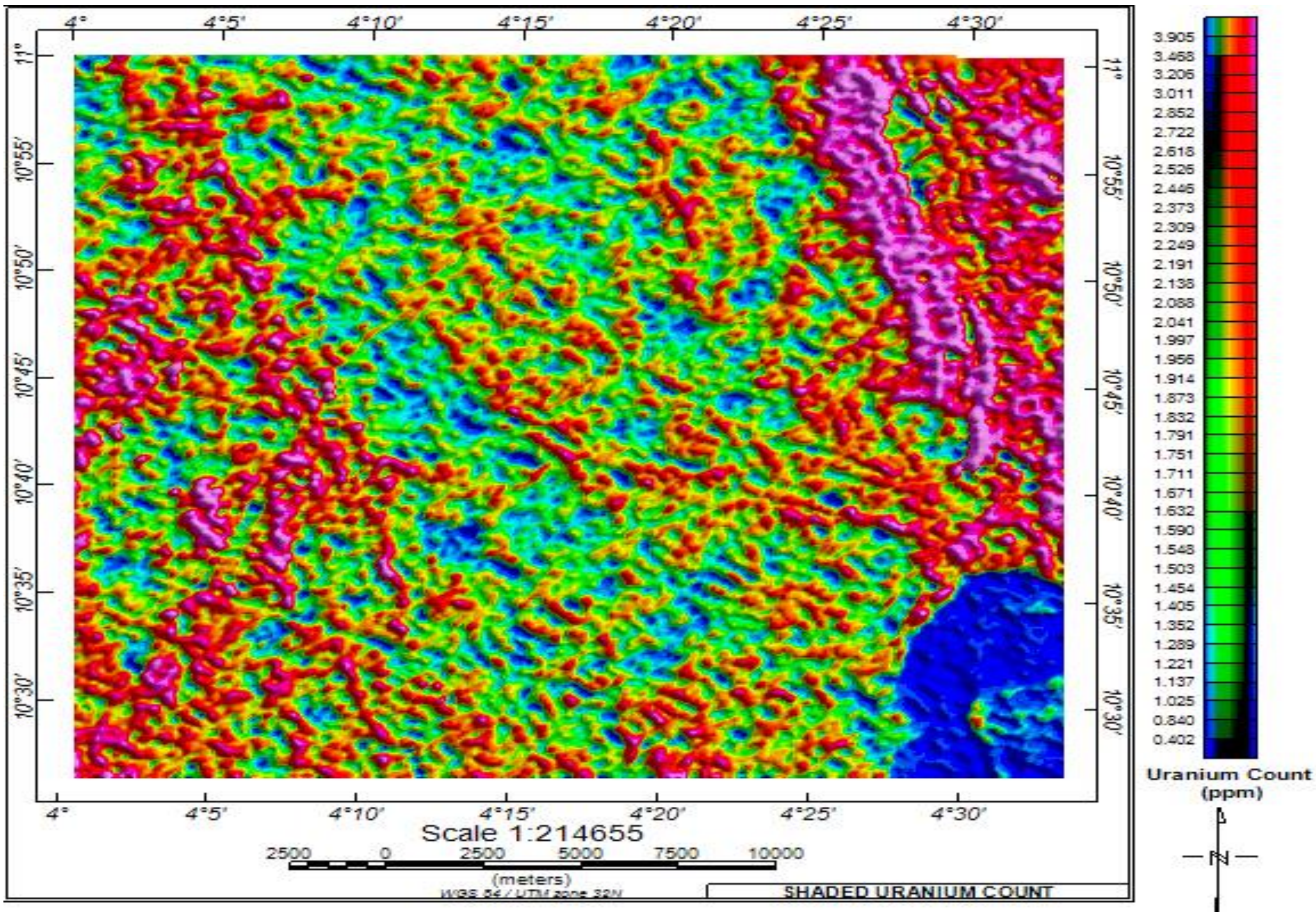

Figure 5. Shaded uranium count map of the study area.

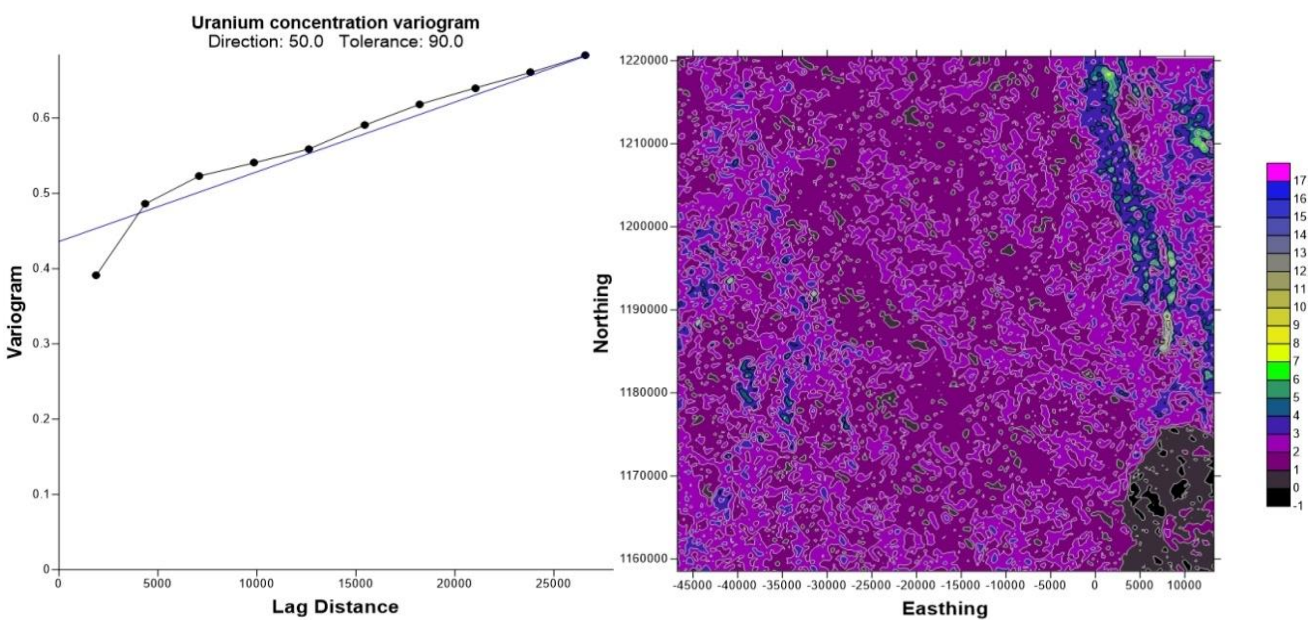

Figure 6. Uranium concentration variogram.

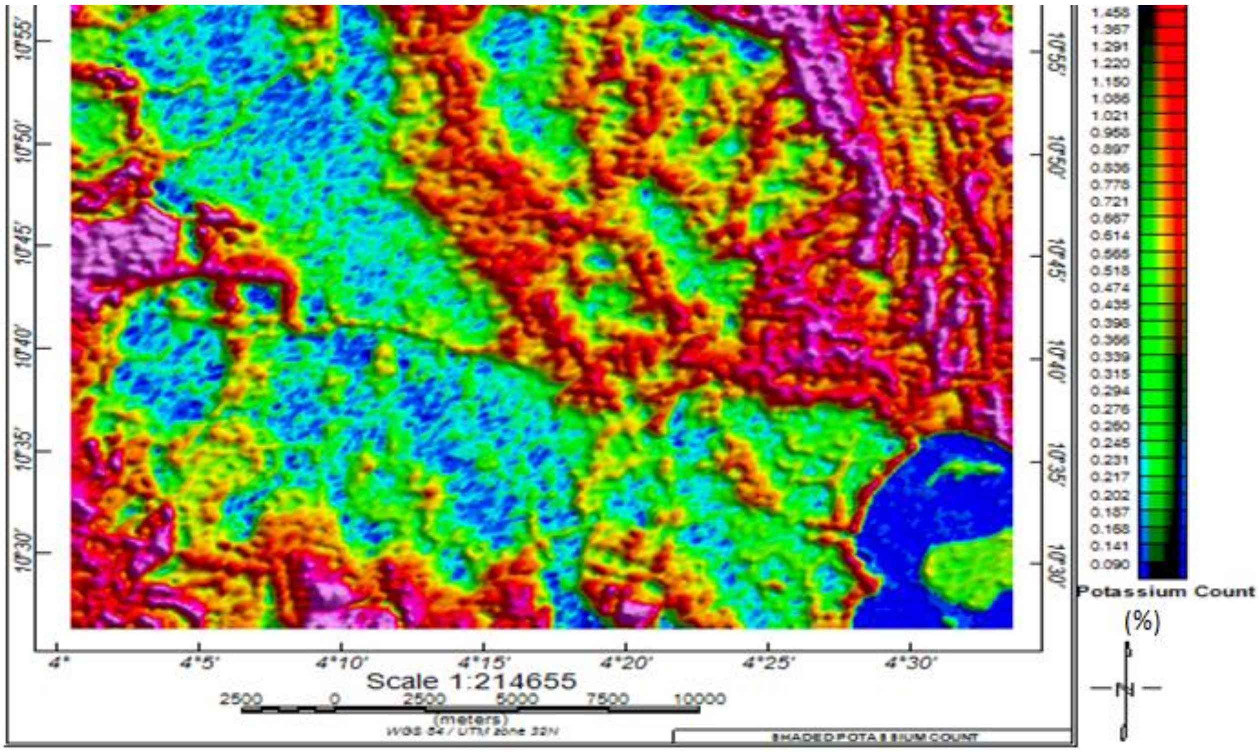

Figure 7. Shaded radiometric potassium anomalies of the study area.

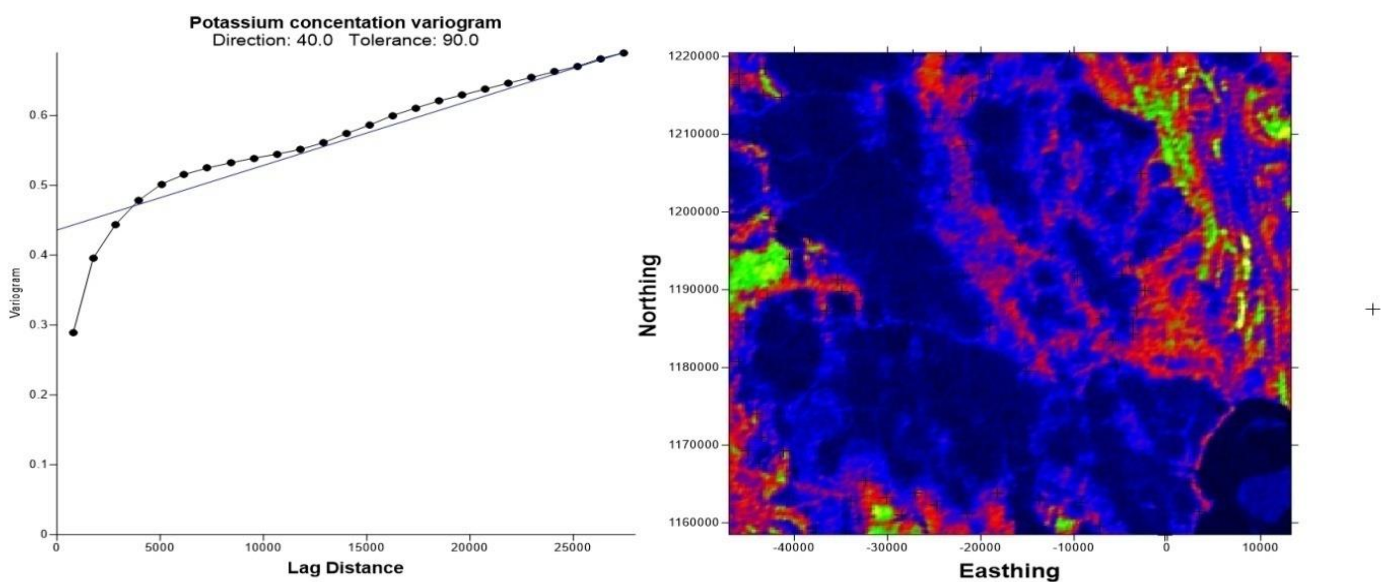

Figure 8. Potassium concentration variogram.

dominated by basement complex rocks, which play host to economic minerals with potassium the most abundant and uranium the second most abundant across the area.

Results from statistics and map analysis have shown that the concentration of potassium is dominant in almost all parts of the study area and is of great advantage to agriculture in the area. Also from the analysis of the maps, the relative lower values of uranium abundances in Birnin Yauri area are roughly related to the presence of sedimentary rocks such as carbonates and sandstones in

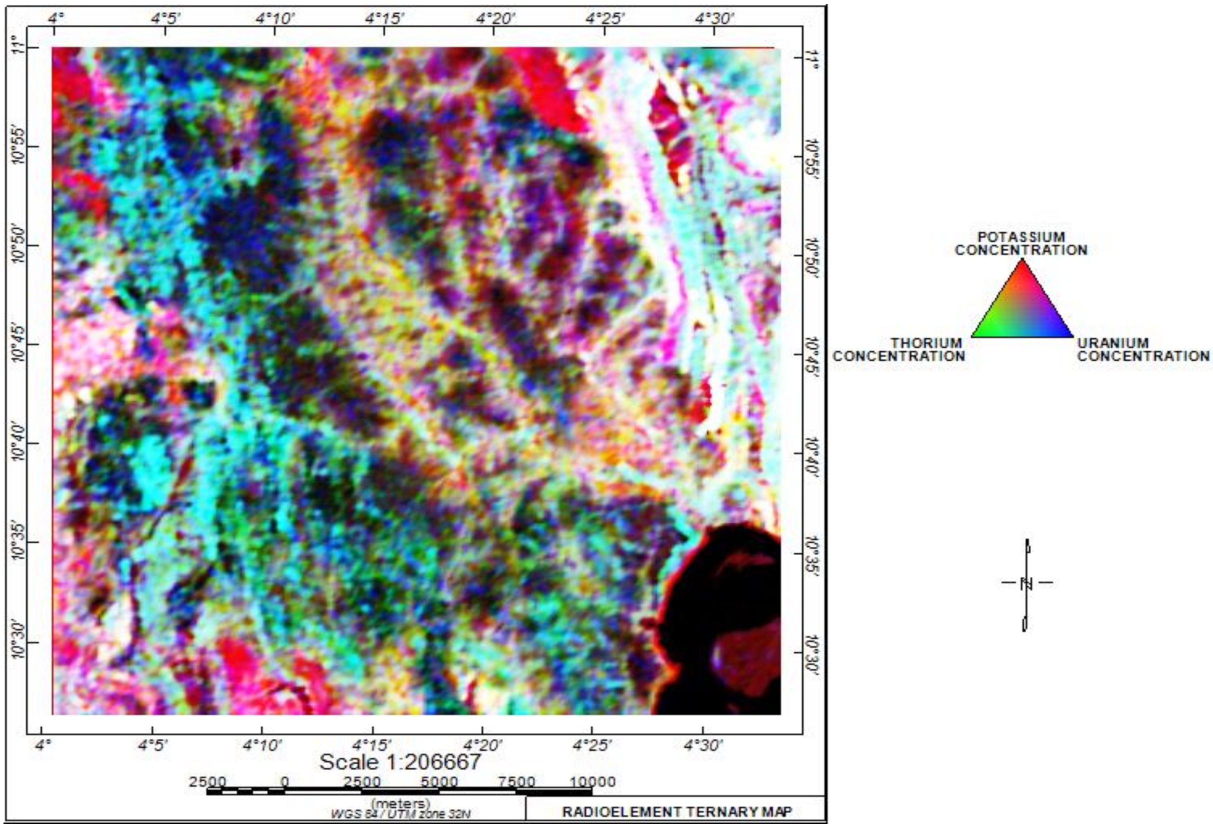

Figure 9. Airborne radiometric ternary map of thorium (th), uranium (u) and potassium (k) abundance.

the study area. Uranium is the second most abundant element in the region with activity concentrations between 0.402 to 3.905 ppm. Thorium is the least abundant of the three elements with concentrations between 0.589 to15.221 ppm. These values obtained correlate with the findings of (Uwa, 1984), which indicate the sparse distribution of radioelement concentration, with potassium being the most abundant and thorium the least abundant.

Conclusion

Airborne radiometric data over a portion along Birnin Yauri, Northwestern Nigeria were analyzed and interpreted with the aim of unravelling the relative abundance of radioelement. The result obtained reveal regions within the study area where radioelements can be located and extracted. The eastern and western flanks of the study area are regions dominated by basement complex rocks, which play host to economic minerals like the radioelement confined along the identified faults, fractures and veins. In view of the economic importance of these radioelements, potassium contents and a host of other uranium contents are sufficiently available across this region particularly along the western flank for uranium and mid central portion of the surveyed region depicting potassium abundance across the vicinity under study. Conclusively, the result obtained can serve as a baseline for further exploration of uranium and potassium content across the area due to the vast abundance visibly portrayed on the map for potassium and uranium content, with only but a few of the thorium content.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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