
EXPLORATION OF RELATIVE ABUNDANCE OF RADIOELEMENT CONCENTRATIONS OVER THE LOWER PART OF THE SOKOTO BASIN, NORTHWESTERN NIGERIA

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Abstract

This study investigates the relative abundance and distribution of radioelements within the lower part of the Sokoto Basin, northwestern Nigeria, using aero-radiometric data. The datasets were obtained from the Nigeria Geological Survey Agency (NGSA) and processed using Oasis Montaj 8.4 and QGIS software. Results revealed that the distribution of uranium, thorium, and potassium is closely associated with geological structures responsible for hosting these radioelements. Depth estimates obtained from Euler deconvolution ranged from –12,242.7 m to 12,100.5 m, indicating the occurrence of both shallow and deep-seated mineralization. The Tambuwal and Kebbe axes exhibited deeper mineralized structures, whereas the Dange and Gwandu axes showed both shallow and deep sources. Potassium was identified as the most abundant radioelement across the study area, with concentrations ranging from 0.108% to 2.064%. Uranium concentrations varied between 0.82 and 5.05 ppm, while thorium concentrations ranged from 4.23 to 18.18 ppm. The observed radioelement distribution is attributed to the dominance of sedimentary formations such as shale and sandstone within the basin. The eastern and western flanks of the study area were identified as zones with significant mineralization potential. The study provides baseline geophysical information for future mineral exploration and environmental investigations within the Sokoto Basin.

Keywords: Aero-radiometric data, Radioelements, Sokoto Basin, Uranium, Thorium, Potassium, Mineral exploration, Northwestern Nigeria.

1. Introduction

Large scale exploration for radioelements in Nigeria began in 1975 with the implementation of high sensitivity aeroradiometric surveys conducted by Fairly Surveys Ltd. and Hunting Geology and Geophysics Ltd. on behalf of the Federal Ministry of Mines and Power. These surveys covered the lower Benue area, the middle Niger region, and the Sokoto Basin. Subsequent ground investigations were carried out by organizations such as the Nigeria Uranium Mining Company (NUMCO), the Nigerian Mining Corporation, the Geological Survey of Nigeria, and the University of Ife.

Despite these efforts, information regarding uranium occurrences in Nigeria remains limited. Considering the increasing energy demand in the country, there is significant potential for uranium exploration and development. Further studies on radioelement concentrations, particularly uranium, are therefore essential for sustainable resource development (Adamu and Ahmed, 2019).

This study focuses on the investigation of radioelement concentrations within the southern part of the Sokoto Basin using aero-radiometric measurements. Gamma-ray spectrometry is an effective tool for mapping geological structures and identifying economically important minerals such as uranium, thorium, phosphates, heavy minerals, and alluvial sands. The study also aims to generate ternary radioelement maps to illustrate the spatial distribution of uranium, thorium, and potassium within the study area.

1.1 Statement of the Problem

The southern Sokoto Basin lacks comprehensive information regarding the concentration and distribution of radioelements. This gap limits geological exploration, environmental assessment, and mineral resource evaluation within the region. Consequently, there is a need for detailed radiometric studies to identify mineralized zones and establish baseline geophysical data for future exploration activities.

1.2 Aim and Objectives

The aim of this study is to investigate the relative abundance and distribution of radioelements within the lower part of the Sokoto Basin using aero-radiometric data.

The specific objectives are to:

- i. Determine the concentration levels of uranium, thorium, and potassium within the study area.
- ii. Establish the abundance and spatial distribution of radioelements associated with various rock units.
- iii. Generate DRAD plots and ternary maps of radioelement distributions.
- iv. Identify potential geological structures hosting radioelement mineralization.
- v. Provide baseline information for future exploration and environmental monitoring.

2. Geology of the Study Area

The study area is located within the Sokoto Sedimentary Basin in northwestern Nigeria. The basin is characterized by a gently undulating plain with elevations ranging between 250 and 400 m above sea level. The Dange Scarp represents the most prominent

geomorphological feature within the basin (Obaje, 2009).

The Sokoto Basin forms part of the larger Iullemmeden Basin, whose sediments were deposited during four major depositional phases. The Illo and Gundumi Formations, composed mainly of grits and clays, overlie the Precambrian Basement Complex and represent pre-Maastrichtian continental deposits (Obaje et al., 2022).

The Maastrichtian Rima Group consists of mudstones and friable sandstones represented by the Taloka and Wurno

Formations, separated by the fossiliferous Dukamaje Formation. Overlying the Rima Group is the Paleocene Sokoto Group, which includes the Dange and Kalambaina Formations (Kogbe, 1979).

The uppermost sedimentary sequence is the Gwandu Formation of Eocene age, consisting predominantly of red and mottled clays with sandstone intercalations. The formation is interpreted as continental lacustrine deposits and is widely exposed around Birnin Kebbi, Argungu, and Kalambaina (Kogbe, 1976; Obaje, 2009).

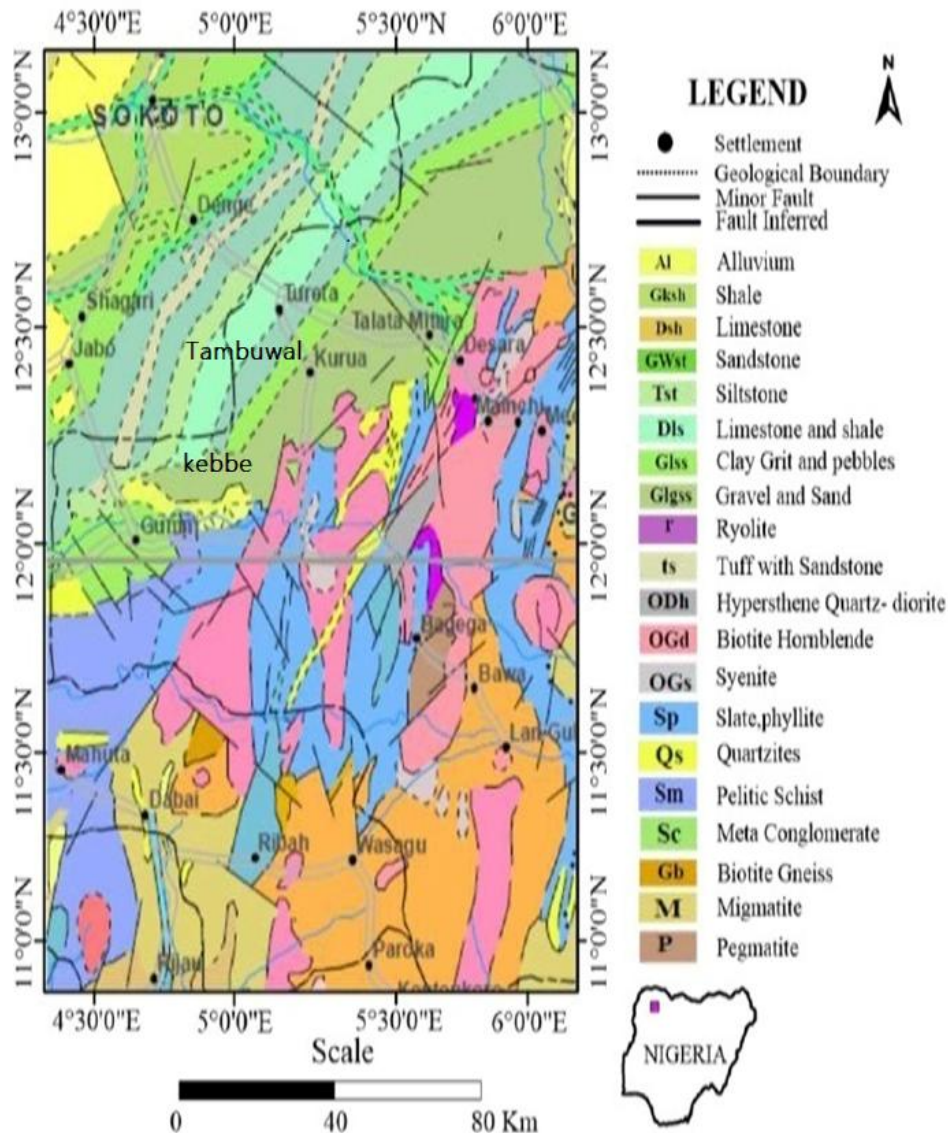


Figure 1: Geological map of the study area (After NGSA, 2009)

2.1 Gwandu/Tambuwal Clay and Grit Group

Raeburn and Tattam (1930) initially referred to these deposits as the “Massive Clay Group” because of their high clay content. Jones (2013) later described them as the Gwandu/Tambuwal Clay and Grit Group, characterized by flat-topped and steep-sided ironstone-capped hills composed of clays, grits, and sandstones of varying grain sizes.

The formation covers approximately 22,000 km² in northwestern Nigeria and exhibits prominent ridges and ironstone-capped hills. Sedimentary structures commonly observed include ripple marks, cross-bedding, graded bedding, and bioturbation structures. The formation is generally interpreted as non-marine and lacustrine in origin (Kogbe, 1972).

3. Theoretical Background

3.1 Uranium

Uranium is a highly radioactive element widely distributed in the Earth’s crust. It commonly occurs in granites, pegmatites, and sedimentary rocks. During weathering processes, uranium may become mobilized and concentrated under favorable reducing conditions (Dickson and Scott, 1997).

3.2 Potassium

Potassium is an important constituent of felsic igneous rocks and silicate minerals such as feldspars and micas. Potassium concentrations are generally higher in felsic rocks than in mafic rocks due to magmatic differentiation processes.

3.3 Thorium

Thorium belongs to the actinide series and occurs mainly in resistant minerals such as monazite and zircon. Thorium is relatively immobile during weathering and is therefore useful in identifying geological formations associated with radioactive mineralization.

4. Materials and Methods

4.1 Data Acquisition

The aero-radiometric datasets covering Tambuwal, Kebbe, Dange, and Gwandu were obtained from the Nigeria Geological Survey Agency (NGSA). The airborne survey was conducted in 2009 using a high-sensitivity 256-channel airborne gamma-ray spectrometer.

The survey was flown at an altitude of approximately 100 m with flight-line spacing ranging from 200 to 500 m. The spectrometer system consisted of downward-looking NaI(Tl) detectors and upward-looking detectors for atmospheric correction.

Potassium concentrations were recorded directly in percentage (%), while equivalent uranium (eU) and equivalent thorium (eTh) concentrations were recorded in parts per million (ppm).

4.2 Data Processing

The acquired datasets were processed using Oasis Montaj 8.4 and QGIS software. Processing procedures included:

- Background correction
- Stripping correction
- Height correction
- Sensitivity correction
- Energy calibration

- Spectral smoothing
- Radon background correction

Euler deconvolution techniques were applied to estimate the depth and structural characteristics of radioelement sources.

4.3 Ternary Radioelement Mapping

Ternary maps were generated by assigning red, green, and blue colors to potassium, thorium, and uranium concentrations respectively. These maps were used to interpret the spatial distribution and relative abundance of the radioelements.

5. Results and Interpretation

5.1 Uranium Distribution

Uranium concentrations ranged from 0.82 to 5.05 ppm across the study area. High uranium anomalies were predominantly observed within the eastern and central portions of the study area, particularly around Kebbe and Gwandu. The anomalies are associated with sandstone, siltstone, migmatite, and mica schist formations.

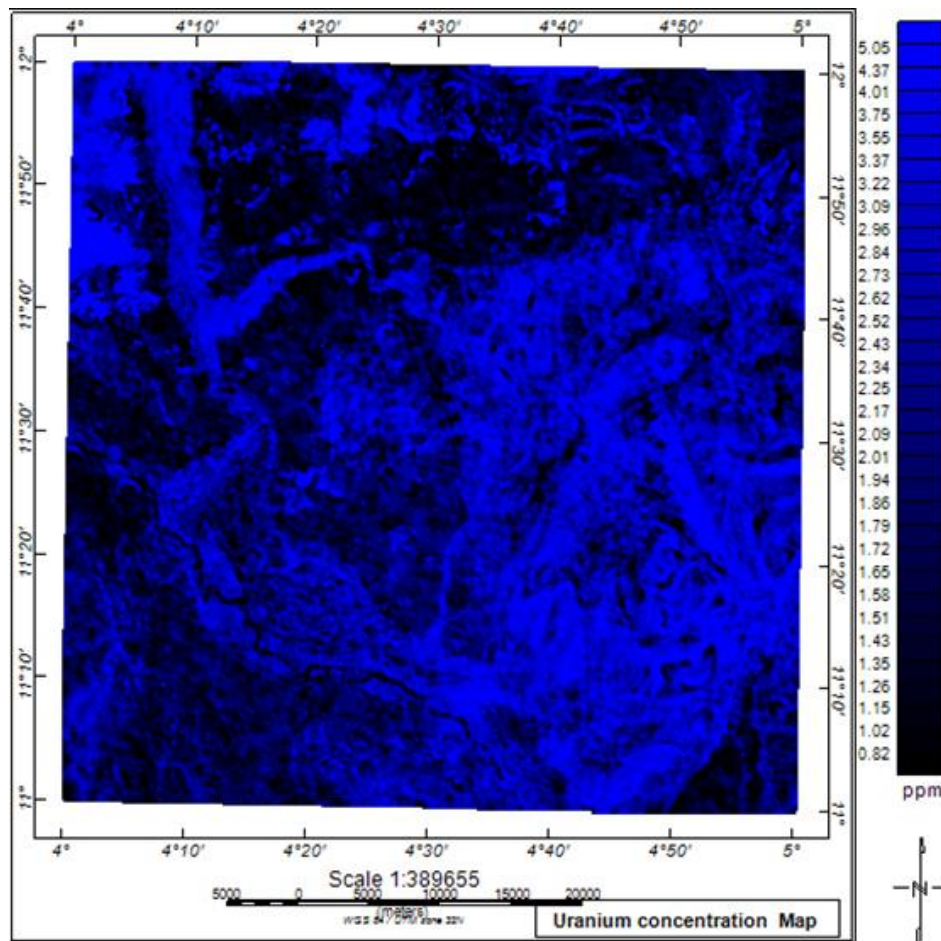


Figure 2: (a) The Uranium Concentration Map and (b) Uranium Composite map

Figure 2(a) shows the thorium count map with activity concentrations ranging from

4.23 to 18.18 ppm. High thorium concentrations, associated with felsic and

igneous intrusive rocks, are widely distributed across the northwestern part of the study area, while low concentrations are linked to mafic rocks and hydrothermal alteration. The highest values (6.93–18.18 ppm) occur mainly in Kebbe and Gwandu areas, whereas lower values (4.23–6.93 ppm) are observed around Tambuwal and Dangedue to the presence of sandstone, siltstone, and mica schist formations.

5.2 Thorium Distribution

Thorium concentrations ranged from 4.23 to 18.18 ppm. Areas with high thorium concentrations were mainly located within the eastern and western sections of the study area. Low thorium concentrations were observed between Tambuwal and Dange.

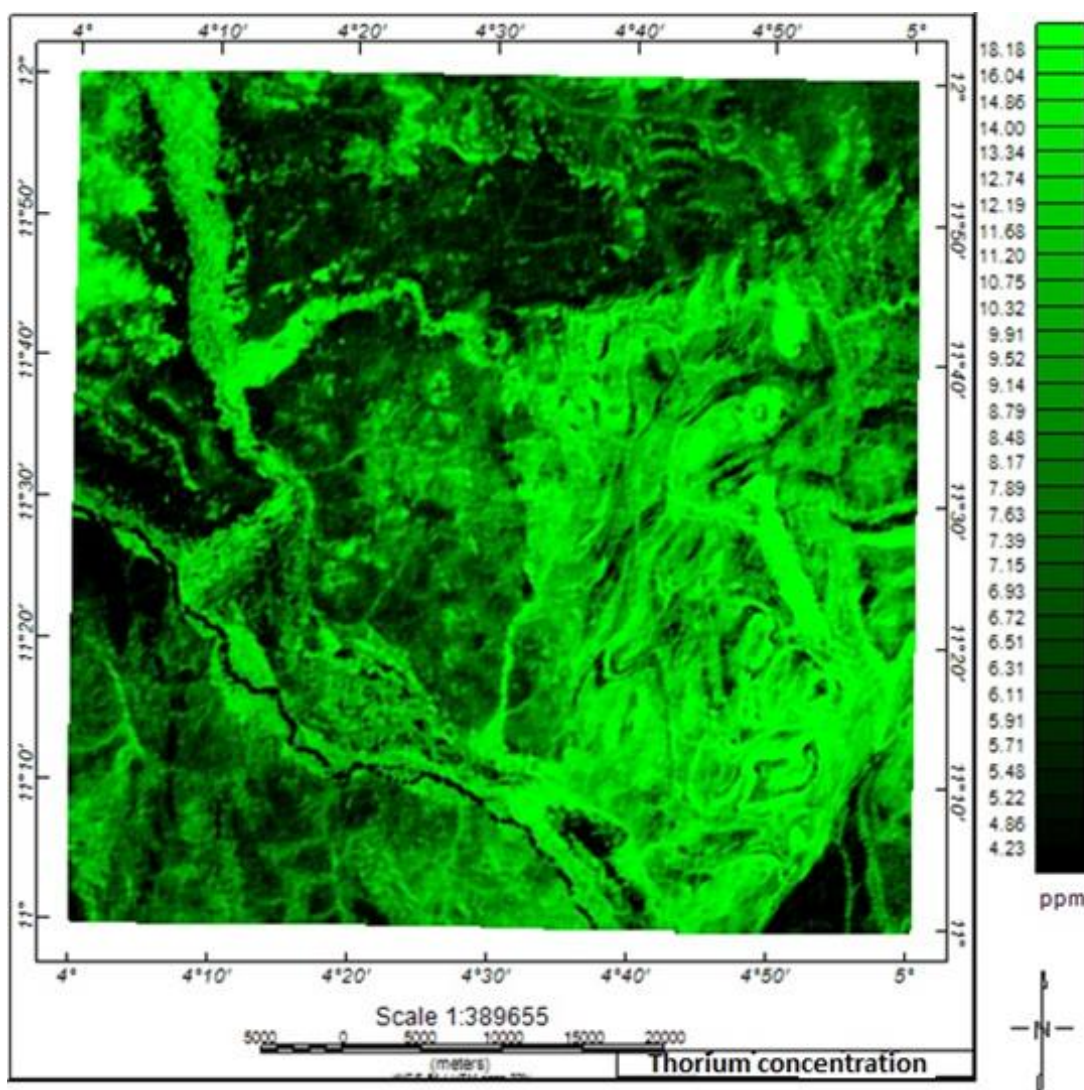


Figure 2(a): Thorium Composite Map

Figure 2(b) presents the thorium composite map, indicating equivalent thorium (eTh) concentrations ranging from 4.080 to 12.309

ppm, with notable thorium enrichment along the eastern and western parts of the study area.

5.3 Potassium Distribution

Potassium concentrations varied between 0.108% and 2.064%. High potassium

concentrations were concentrated around Gwandu and parts of the southeastern region. These concentrations are linked to felsic rocks and potassium-bearing minerals.

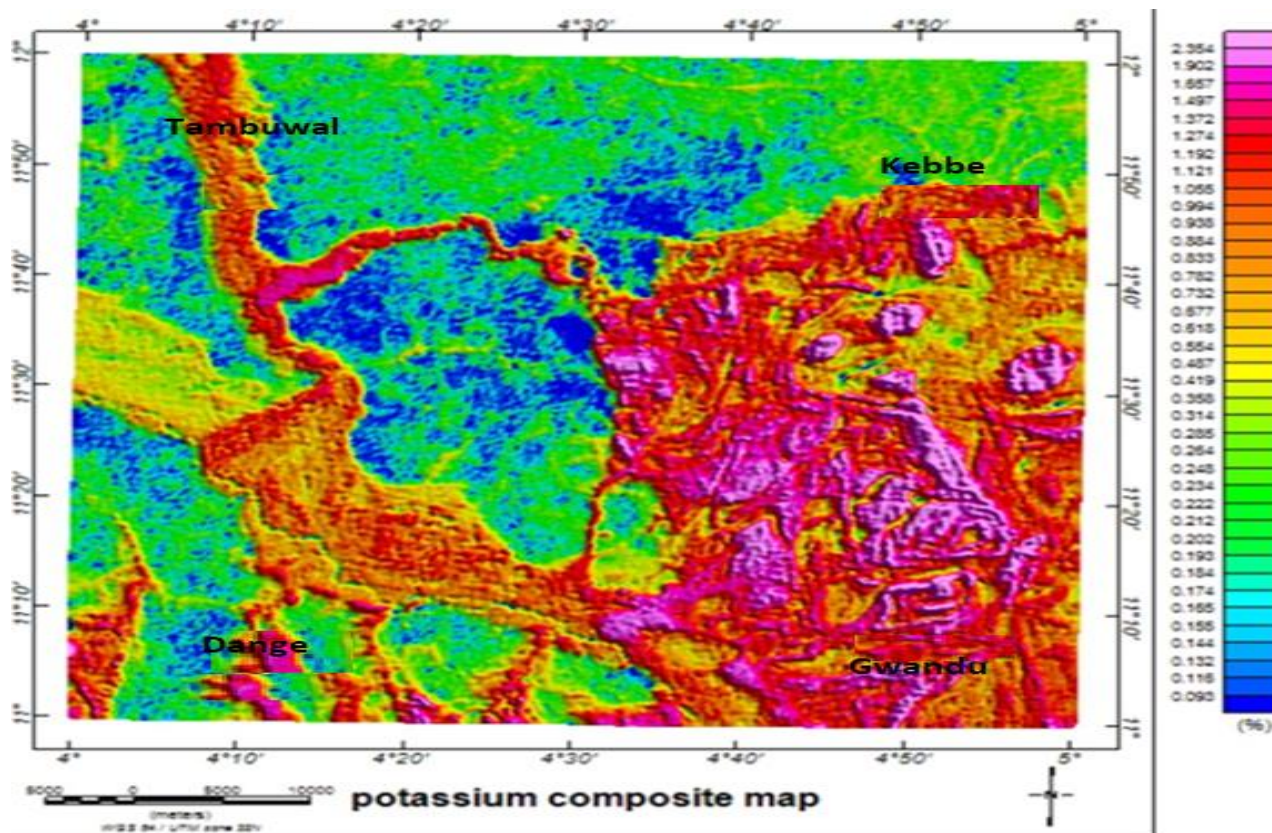


Figure 3(a): Potassium Composite Map

Figure 3(a) presents the shaded potassium count map with activity concentrations ranging from 0.108 to 2.064%, showing major potassium anomalies along the eastern part of the study area. Potassium radiation is mainly associated with K-feldspar minerals such as microcline and orthoclase, as well as micas commonly found in felsic igneous rocks, while lower concentrations occur in mafic rocks. The map indicates both high and low potassium distributions as shown by the legend.

5.4 Euler Depth Solutions

Euler depth estimates ranged from -12,242.7 m to 12,100.5 m, indicating the presence of both shallow and deep-seated mineralized structures. Tambuwal and Kebbe exhibited deeper sources, whereas Dange and Gwandu showed mixed shallow and deep sources.

5.5 Ternary Radioelement Map

The ternary radioelement map revealed that potassium is the dominant radioelement within the study area, followed by uranium and thorium. The eastern and western flanks

of the study area are dominated by important minerals.
sedimentary rocks hosting economically

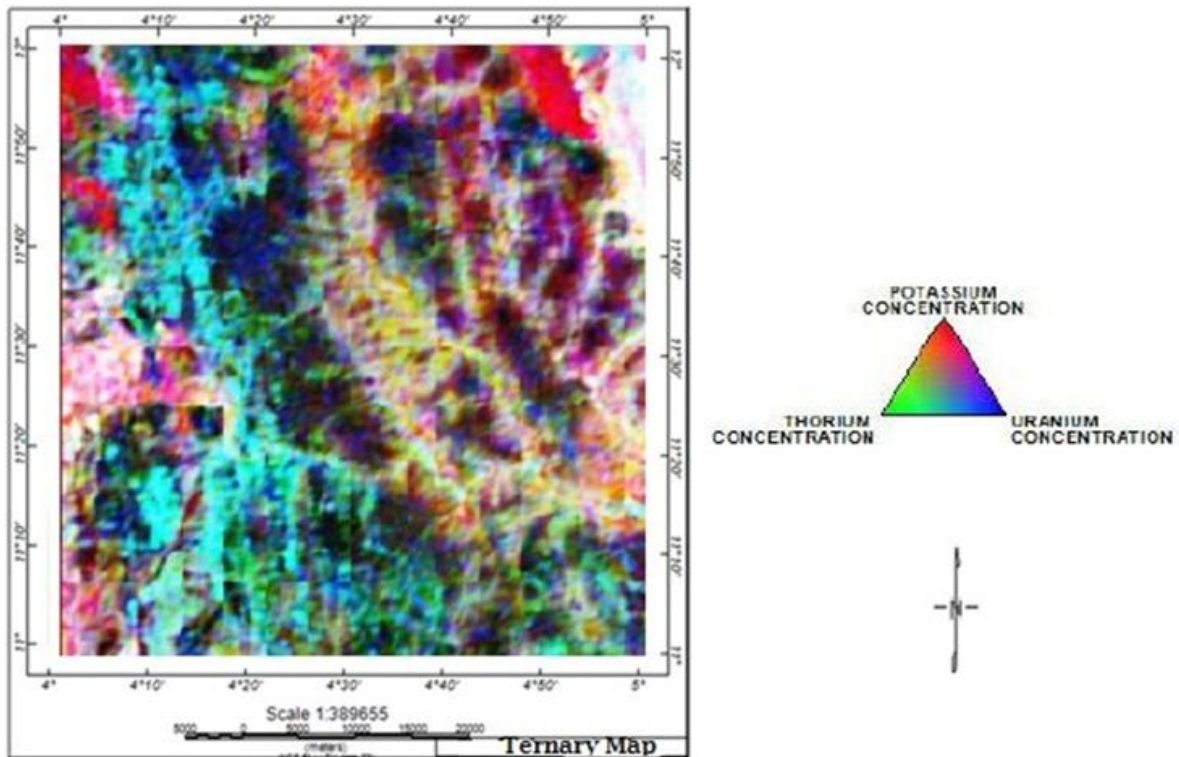


Figure 5. Ternary Radioelement concentration Map

Ternary image of the analyzed data.

The table 1. Represent how the various colors that appear in a ternary image can be interpreted. Red areas are high in Potassium, green areas are high in Thorium and blue areas high in Uranium. Cyan areas are high in Thorium and Uranium; magenta areas are high in

Potassium and Uranium and yellow areas are high in Potassium and Thorium. White areas have high levels of all three radio-elements and black areas have low levels of all the three radio-elements of interest (U, Th and K).

Table 1. Preparation and Interpretation of Ternary Images of Spectrometry data (Cranfield University, UK 1990).

Radio-element	Uranium	Thorium	Potassium
Red	Low	Low	High
Green	Low	High	Low
Blue	High	Low	Low
Cyan	High	High	Low
Magenta	High	Low	High
Yellow	Low	High	High
White	High	High	High
Black	Low	Low	Low

7. Conclusion

This study analyzed airborne radiometric data over the lower part of the Sokoto Basin with the aim of determining the relative abundance and distribution of radioelements. The results identified zones of uranium, thorium, and potassium enrichment associated with sedimentary formations and geological structures.

The study demonstrates that the eastern and western flanks of the basin possess significant mineralization potential. Potassium was found to be the most abundant radioelement, while uranium concentrations indicate potential for future exploration activities. The generated radiometric maps provide valuable baseline information for mineral exploration and environmental monitoring within the Sokoto Basin.

Recommendations

1. Ground radiometric and magnetic surveys should be conducted to validate the airborne radiometric results.
2. Future studies should incorporate high-resolution gamma-ray

spectroscopy and geochemical analyses.

3. Detailed geological mapping should be undertaken in areas with high uranium and potassium anomalies.
4. Environmental impact assessments should accompany future exploration activities.

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