

RESEARCH ARTICLE

CHARACTERIZATION OF HYDROTHERMAL ALTERATION ZONES IN PARTS OF NORTH-CENTRAL BASEMENT COMPLEX OF NIGERIA FOR SOLID MINERAL DEPOSITS

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ABSTRACT

This study aimed at mapping the lithological formations and hydrothermally altered zones that are fruitful for the mineral potential in parts of the north-central basement complex of Nigeria using aeroradiometric data. The resulting radioelement of uranium (eU), thorium (eTh) and potassium (K%) anomaly data were subsequently used to depict the lithologies and hydrothermal alteration zones using ternary and potassium to thorium ratio imageries respectively. The abundance of K, eTh and eU varies in proportion of 0.12 to 4.37 %, 5.49 to 29.41 ppm and 0.49 to 8.29 ppm. The potassium to thorium ratio ranges from 0.01 to 0.38 %ppm revealing the hydrothermally altered zones to be around Dadabiri, Pai, Kwali, Gao and Tagwai. Hence, the prominent minerals identified in the study include albite (feldspar), granite, dolerite, gold and muscovite. The distribution and extent of these mineralized zones fall within a broad northeast-southwest trending axis.

KEYWORDS

Hydrothermal, Characterization, Minerals, Alteration, Basement

1. INTRODUCTION

The application of aeroradiometric surveys has gained popularity in recent decades due to advancements in acquisition, processing, and interpretation techniques (Ogungbemi et al., 2018). It has become a powerful tool adopted by geo-scientist in gaining information about the composition and structure of rocks and soil (Ajeigbe et al., 2014). The radiometric measurement can be used to confirm the presence and abundance of radioelements (e.g., uranium (U), thorium (Th) and potassium (K)). These radioelements occur naturally and are typically found as trace contents in rocks and soil (Telford et al., 1990). The analysis of these radioelements provides useful insights into numerous geological processes and phenomena (Dentith and Mudge, 2014). For instance, the indirect measurements of uranium and thorium activity concentrations warrants the usage of the prefix equivalent as thus uranium (eU) and thorium (eTh). The measurement of these radioelements is usually related to certain lithological formations which may indicate presence of ore deposits (Urquhart, 2013). The direct measurement of potassium (K%) on the other hand, is an essential element in many rocks and minerals and can provide information about the age and geological history of a particular area (Sanusi and Amigun, 2020). To quantify the abundance of these radioelements and their implications to mineralised deposits, geoscientists used K in percentage to depicts the anomalus zones which are directly associated with low eTh regions (Sanusi and Amigun, 2020; Saleh et al., 2022; 2023).

The basement complex in northcentral Nigeria, which the present study area falls into, is composed of various rock types, including gneisses, granites, migmatites, schists, and quartzites (Obaje et al., 2006). This basement complex has significant mineral resources like gold, tin, tantalite, columbite, lead, zinc, and gemstones like tourmaline and topaz (Ajibade et al., 2008). These minerals have been mined in the region for many years and contribute to Nigeria's economy (Ajakaiye, 1985;

Adekoya, 2003).

Despite the northcentral Nigeria basement complex mineral resources potentials (Adedoyin et al., 2014; Woakes et al., 1987; Garba, 1988, 2000; Ramadan and Fatta, 2010; Aliyu et al., 2021; Saleh et al., 2020), there are under studies in the mapping lithologies and characterizing of the ideal mineralised zones in the present study area. It is in this regard, this study utilized aeroradiometric data covering a segment of northcentral, Nigeria basement complex to identify the lithological formations and hydrothermally altered zones that are fruitful for solid minerals.

2. LOCATION AND GEOLOGY OF THE STUDY AREA

The study area spans longitudes 6° 30' to 7° 30'E and latitudes 8° 00' to 9°30'N (Figure 1) with estimated area of 18000 Km². This study area fall within the north-central part of Nigeria.

Reports indicate that the region, as stated in a study in 1976, has yielded a wide range of mineral resources, such as iron ores and gold (Burke et al., 1976). The area is characterized by several geological features, including migmatitic precambrian basement rocks, proterozoic metasedimentary belts (specifically schist), granitoids, and tertiary sediments. Within the precambrian basement, there is a diverse array of rocks, including sheared rocks, migmatite, migmatitic gneiss, banded gneiss, and granite gneiss. Furthermore, the Proterozoic metasedimentary belts consist of undifferentiated schist, phyllite, and slate.

The schist belts in the study region as shown in figure 2, is part of the north-central Nigeria's basement complex (see figure 3), exhibiting a range of lithological features such as phyllites, amphibolites, pelitic schists, banded iron formations, carbonate rocks (including marbles and dolomitic marbles), and clastics with varying grain sizes. It is noteworthy, among these schist belts are the Zungeru, Igara, and Muro hills, situated

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respectively in the states of Niger, Kogi, and Nasarawa. These schist belts are primarily concentrated to the north and east of Abaji, extending

northward east of Shanzhi and southward into the southern part of Yenche.

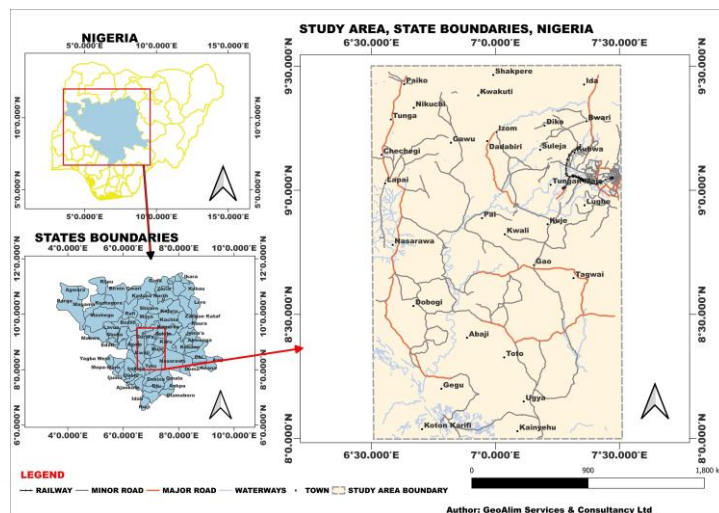


Figure 1: Location map of the study area

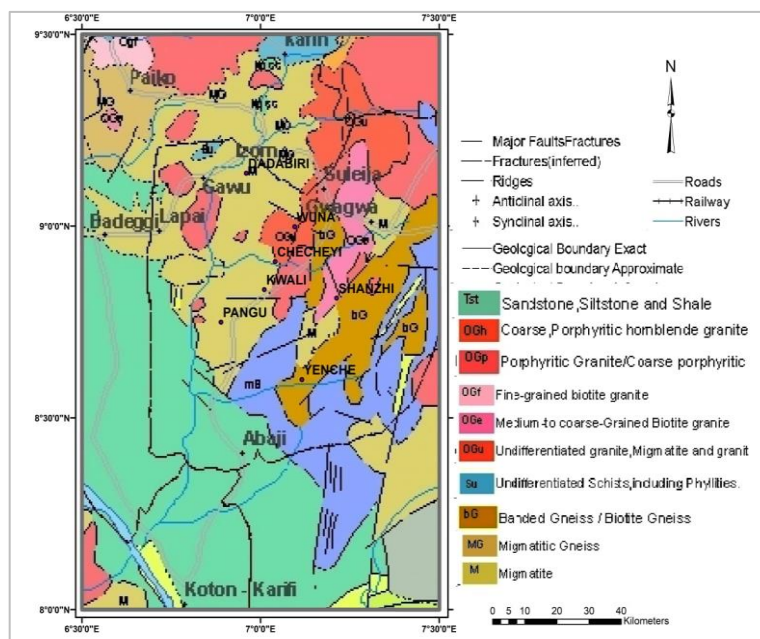


Figure 2: Geological map of the study area

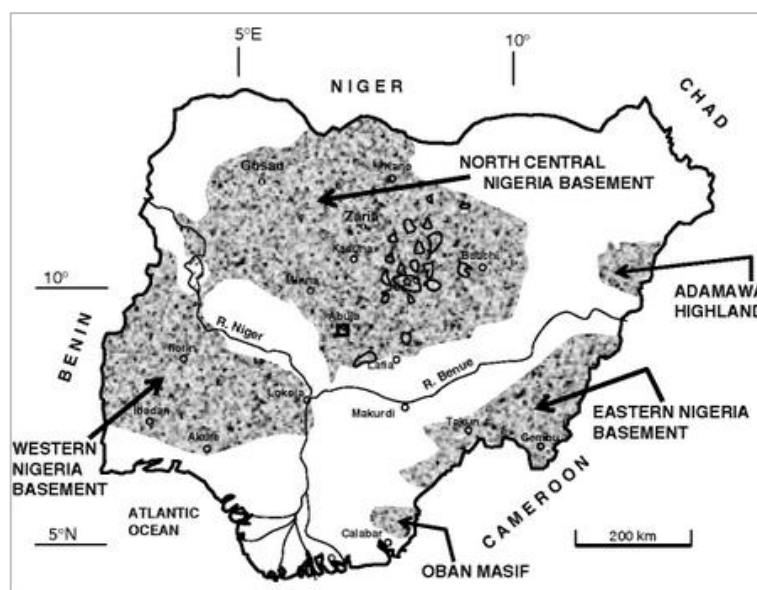


Figure 3: map of Nigeria showing the North Central Basement (Obaje, 2009)

3. MATERIALS AND METHOD

3.1 Aeroradiometric Data Source

The study employed high-quality aerial radiometric data, obtained from the Nigeria Geological Survey Agency (NGSA) in 2008, covering Nigeria. Fugro Airborne Surveys Limited, a Canadian firm was contracted by the government of Nigeria to carry out the acquisition with the main purpose of providing geological and geophysical data. The data was digitized and presented as a composite grid at a scale of 1:100,000. It was obtained during a flight at an altitude of 80 meters, with line spacing of 500 meters and tie line spacing of 2000 meters. For this work, six half-degree radiometric data sheets 185 (Paiko), 186 (Abuja), 206 (Gulu), 207 (Kuje), 227 (Koton Karfe) and 228 (Katakwa) was knitted to form the study area, covering about 18,000 Km². By applying the minimum curvature method, enhanced radiometric distribution maps of the primary radioelements (Potassium, Thorium, and Uranium) were produced. The radiometric signatures associated with the local mineralization are reflected in these produced maps.

The ternary map also known as composite image was created by assigning red, green, and blue colours to K, eTh and eU respectively as well as K/eTh ratio was estimated. These composite map and K/eTh ratio were used in mapping lithological formations and hydrothermal alterations respectively.

4. RESULTS AND DISCUSSION

Figures 4, 5 and 6 show the individual concentration maps for the three radioelements (Potassium, Thorium and Uranium) respectively.

Furthermore, Figures 7, 8 and 9 show the potassium/thorium ratio, the total count (TC) and the ternary maps respectively for the study area.

4.1 Potassium (K) Anomaly Map of The Study Area

The potassium (K) map in Figure 4, shows different degrees of potassium concentrations starting from 0.12 to 4.37 % which reveals different rock units and alterations in the area. Potassium often increases during signature alterations (Wilford et al., 1997). However, weathering usually decreases the intensity of the signature and alterations (Dickson et al., 1997). The blue colour corresponds to low K values whilst pink corresponds with very high K values. The colour red represents moderately high to high K values and the shades of orange to yellow colour represent or are associated with moderately low K values. These pinkish colorations corresponding to very high K values are observed in areas around Nikuchi, Gawu, Izom (North of Dadabiri) and north of Tungan Maje. Also clearly observed are the areas around south of Kwali (Checheyi), south-east of Kuje (Shanzhi), west of Koton Karfe (south-western part of the study area) and the north-east and south-east of Bwari which show high K anomalies. The moderately high K anomalies as indicated by red colour can be observed in the map around Pai, Kwali and Tagwai (north-west of Toto). The blue colour which is indicative of low anomalies of K found around south-western portion of the study spreading across north and east of Ugya; north of Abaji and east of Toto. The areas with high K concentrations can be as a result of the presence of Biotite granite, undifferentiated granite, medium to coarse-grained biotite granite, granite and granite porphyry) and the metasedimentary/metavolcanic in the area (pelitic/muscovite schists, undifferentiated schist including phyllites, granite gneiss and migmatite and granite gneiss) as shown in Figure 2.

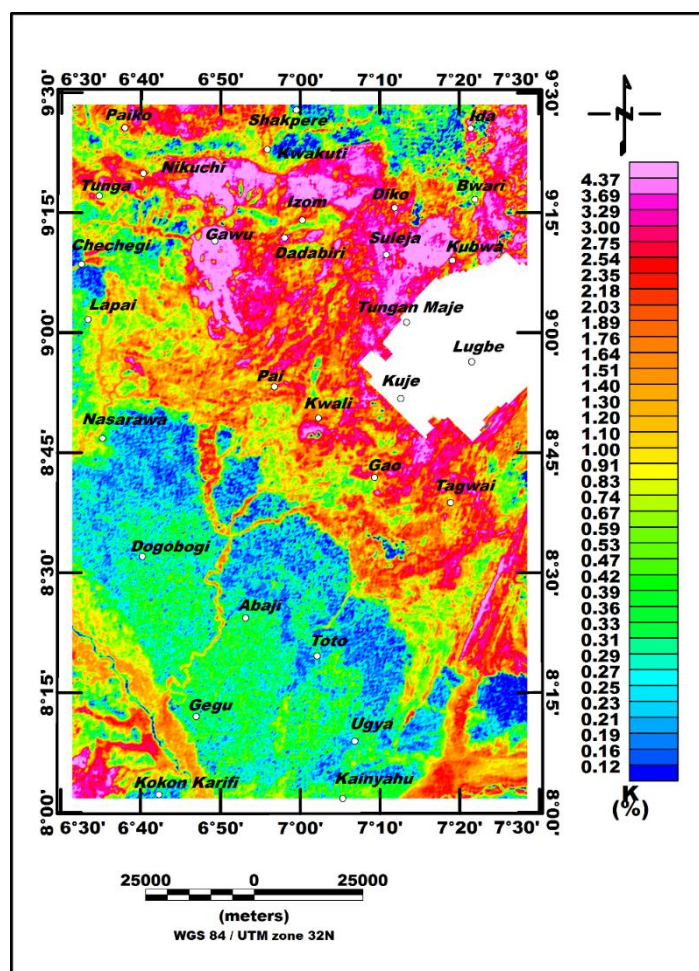


Figure 4: Potassium anomaly map of the study area.

4.2 Thorium Equivalent (eTh) Anomaly Map of The Study Area

The thorium (eTh) anomaly map in figure 5 shows range of values varying from 5.49 to 29.41 ppm. High eTh anomalies are observed in areas around west of Pai, south-east of Dadabiri up to the northern part of Pai. These pinkish colorations can also be seen in areas around Abaji, Gao; south of Kuje and Gegu; south-west of Abaji (north of Koton Karfe). Small traces of this radioelement can also be seen around Gawu in the north-western part

of the study area, chechegi located west of Gawu and Dogobogi (north-east, south-east of Abaji) as shown in fig 5.

In addition, moderately high eTh anomalies are also seen around Tungan Maje, south of Suleja and round Kubwa located south of Bwari as indicated by redish colouration. The areas around north of Dogobogi, south of Toto, north of Koton Karfe, north of Tungan Maje and north of Kubwa present moderately eTh anomalies. It can also be observed in figure 5, areas

around Tunga and Paiko in the north-western part of the study area, show very low anomalies of eTh. Also areas around Kwakuti and the south-western portion of the study area show low eTh anomalies. It can also be seen that the areas around Nasarawa, Izom, Diko and Kubwa have moderately low thorium anomalies. The relatively moderate eTh anomalies can also be seen around northern part of Kwali and as well as the north-eastern portion of the study area (Idah). From the map (figure 5), the eTh can be grouped into high (> 24.06 ppm), moderately high (16.90 to 22.98 ppm), moderately low (10.22 to 22.00 ppm) and < 10.22

ppm as low anomalies.

In view of these, areas of high eTh anomalies are attributed to the Pan-African older granitoids in the area (such as biotite and granite, undifferentiated granite, biotite granite, medium to coarse-grained biotite granite, granite and granite porphyry) and metasedimentary/metavolcanic (pelitic/muscovite schists, undifferentiated schist including phyllites, granite gneiss and migmatite and granite gneiss).

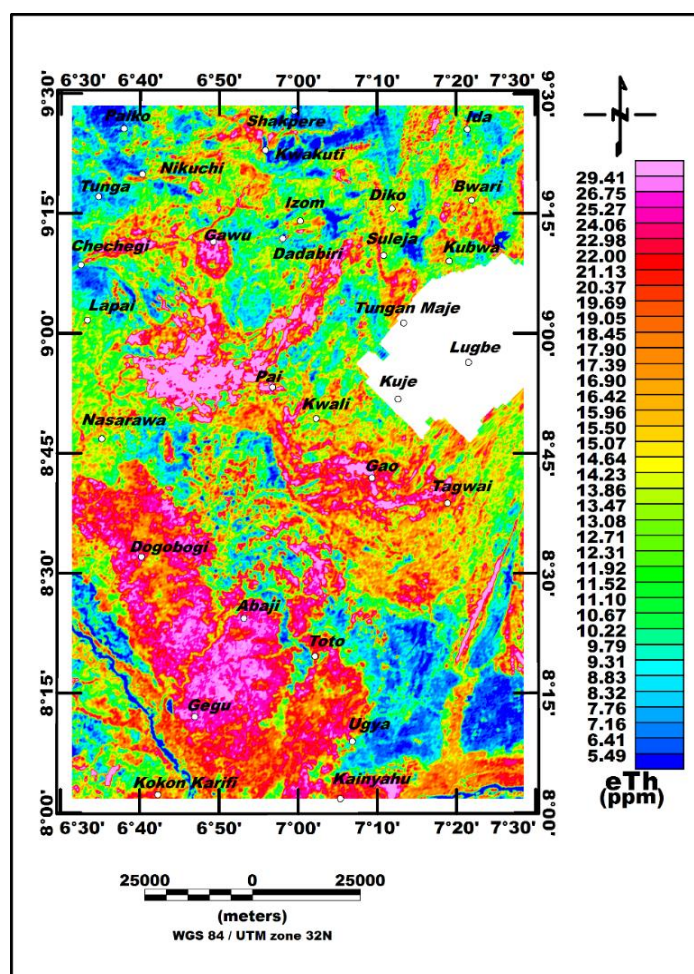


Figure 5: Thorium equivalent (eTh) anomaly map of the study area.

4.3 Uranium (eU) Anomaly Map of The Study Area

Fig. 6 represent the eU anomaly map. Uranium as an element is mobile in hydrothermal and other geological processes; occurrence of uranium in a given location may not necessarily be accompanied by the presence of potassium (Airo, 2007). The eU map shows various anomalous signatures varying from 0.49 to 8.29 ppm. The eU concentrations can be relatively grouped as high (>6.34 ppm), moderately high (3.99 ppm–6.34 ppm), moderately low (1.88 to 3.99 ppm) and low (< 1.88 ppm). The northern part of the study area like Paiko, Tunga, Shekperere, Izom and Dadabiri shows weak appearance of this radiogenic element. Also, Tunga Maje, Idah and Kubwa have low occurrence. It can be decipher from the map that the south-east section of the study area (area around east of Ugua) has low occurrence of uranium. However, uranium occurs in high proportion around south of Gawu, north and south of Dogobogi, south of Abaji, north and east of Gegu and south of Toto. Also, areas of high eU concentrations just as eTh map are attributed to the Pan African Older Granitoids in the area (Undifferentiated granite, Biotite Granite, medium to coarse-grained Biotite Granite, Granite and Granite porphyry) and the Metasedimentary/Metavolcanic in the area (Pelitic/Muscovite schist, undifferentiated Schist including Phyllites, Granite Gneiss and Migmatite and granite gneiss).

4.4 K/eTh Ratio Map

A map of potassium to equivalent thorium, or K/eTh, is shown in Figure 7. Since potassium is often more mobile than thorium in geological processes, regions of hydrothermal alteration are characterized by potassium enrichment, can be identified by K/eTh ratio anomalies (J). However, it's critical to note that, in the majority of varieties of rocks, the

potassium to thorium ratio is comparatively consistent, usually ranging from 0.17 to 0.2 K/Th in %/ppm (Hoover and Pierce, 1990). Rocks can be said to be Potassium-biased or thorium-biased if they contain K/ eTh ratios that are outside of this usual range (Portnov, 1987). In this study, the %K/eTh values range from 0.01 to 0.38 as shown in fig. 7 and due the high mobility of potassium than thorium, the enhanced K/eTh ratio anomalies can be identified with hydrothermal alteration zones which is a result of high potassium enrichment. The hydrothermally altered zone, indicated by the pink colour (Figure 7), is defined as having a K/Th ratio greater than 0.17%/ppm. The areas around south of Gawu, Nikuchi, east of Paiko, north of Izom, east of Suleja, west of Diko and east of Bwari (located in the northern part of the study area) have high values of this ratio. Potential mineral deposits are marked by the high K/Th ratio values, which can be described as areas with promising hydrothermal alteration (Akinlalu, 2023). This alteration zone is also visible around south of Kwali, south of Gawu, south of Suleja, south of Bwari, west of Koton Karfe and south-east of Tagwai (between latitude N8°15' and N8°30').

4.5 Total Count Map

The implication of the combined effect of the three radiogenic elements (the %K, eTh and eU) are presented in figure 8. The total count values range from 7.17 to 37.42 cps. The shows high concentration of the total count around Dogobogi, south-west of Abaji, Gegu, west of Pai, Gao, Gawu, south of Ugua and east of Kainyahu. This high concentration of the combined elements is more pronounced in the southwestern part of the study area. The concentration of the total count value is, however, low around Shakpere, Paiko, Tunga, southeastern-northeastern of Ugua and the extreme southeast of the study area.

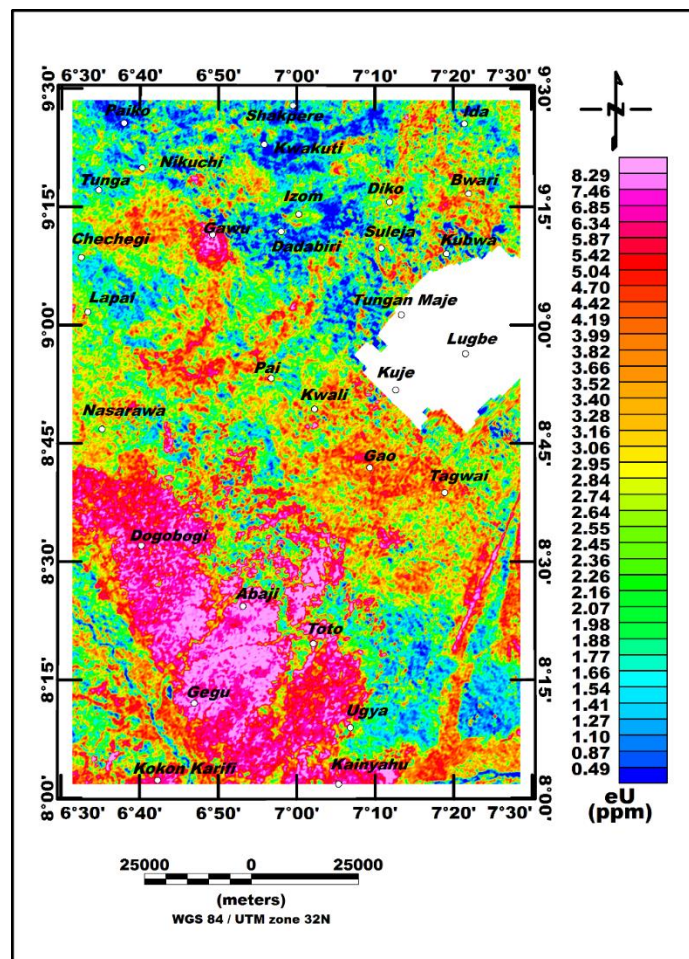


Figure 6: Equivalent Uranium concentration map of the study area

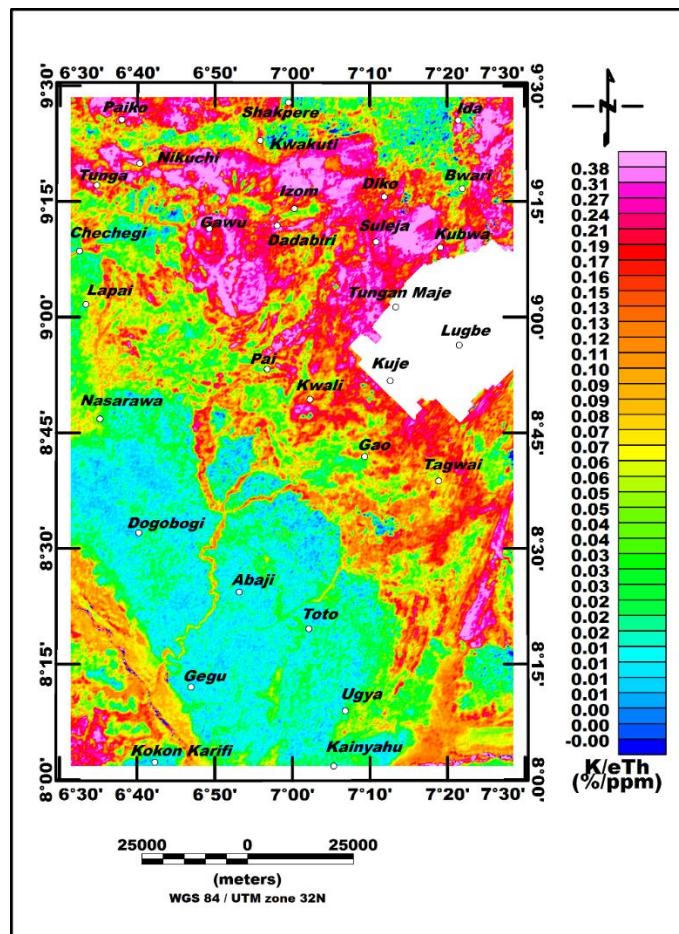


Figure 7: Potassium/Thorium ratio map of the study area

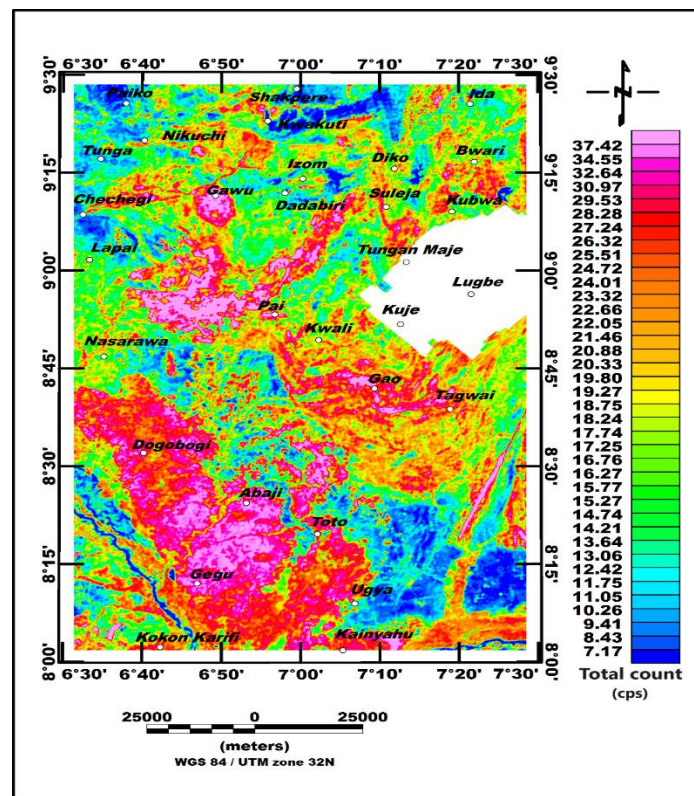


Figure 8: Total Count (TC) map of the study area

4.6 Ternary Map of The Study Area

The radioelement ternary map (Figure 9) depicts the relative abundance of the three key radioactive elements of potassium (K), thorium (eTh), and uranium (eU) within the study area. This ternary map was created by modulating the activity concentrations of K, eTh and eU to red, green and blue colours respectively. The map indicates that K (red colour) anomalies are the most abundant radioelement in the northern part of the study region, while uranium (blue colour) are relatively most abundant in the southwestern portion. Of the three radioelements, thorium (green colour) appears to be the least abundant, with only sparse occurrences noted around Gao, Pai and western part of Pai within the area of the study. Hence, this qualitative interpretation of the ternary image (Fig. 9)

indicates that the three radioactive elements are predominantly present in the northern region of the map. This area corresponds with basement rocks composed of basalt, granitoids, and a migmatite-gneiss complex, as depicted in Figure 2. Moreover, the sparse locations of bright colour in the ternary image represent regions where K, eTh and eU are elevated due to granitic outcrops and sediments derived from granite rocks. The black colour highlights regions with low K, eTh and eU which are possibly caused by the presence of mafic and ultramafic schist rocks. Hence, the location of high K anomalies (Fig. 9) of ternary image coincides with the lithological mapping K (Fig. 7). These coincides are possibly marked as the regions of hydrothermal alterations that could be exploited for solid minerals.

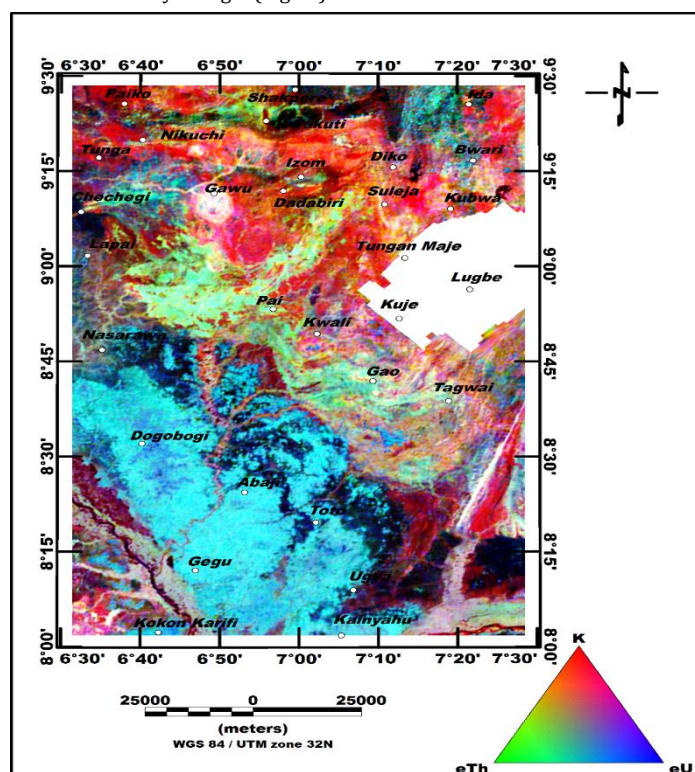


Figure 9: Ternary image of the study area.

5. CONCLUSION

The radiometric data covering a segment of the North-central basement complex of Nigeria were used to mapped lithological units as well as map the hydrothermally altered zones. Since, mineralised zones resulting from radiometric signatures are marked by increasing K and decreasing eTh anomalies. Therefore, the direct interpretations of the K, eTh, eU, TC, ratio and ternary anomaly maps have aided in mapping numerous mineralisation potential locations. These locations around Nikuchi, Gawu, Izom (North of Dadabiri) and north of Tungan Maje, south of Kwali (Checheyi), southeastern of Kuje (Shanzhi), west of Koton Karfe (south-western part of the study area) and northeastern and southeastern are marked by high K and low eTh anomalies. In addition, the coincidence of the regions of K anomalies and high K/eTh ratio are tentatively interpreted as the hydrothermally alteration zones with high degree of polymetallic minerals. This study has aided in depicting the lithologies and also reveals the solid minerals potency of the study area.

CONFLICT OF INTEREST

Authors declare that they do not have any conflict of interest whatsoever.

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