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INTERPRETATION OF RADIOMETRIC ANOMALIES OVER SOME PARTS OF THE LOWER BENUE TROUGH NIGERIA, USING HIGH RESOLUTION AERO-RADIOMETRIC DATA (HRAR)

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ABSTRACT: *The aero-radiometric data of these areas were employed to investigate the radioactive properties of rocks, with the aim of interpreting the concentrations of the principal radioactive elements (^{40}K, ^{238}U, ^{235}U and ^{232}Th) and possible hydrothermally altered zones that can host iron rich minerals. The radiometric data was subjected to enhancement techniques of producing concentration maps of Potassium, Thorium and Uranium. The total count map, ratio map of K/Th and the ternary image map were also produced to aid the interpretation process. The results from the Potassium, Thorium and Uranium maps displayed variations of high, moderate and low concentrations. The concentrations of these elements further mapped geology by distinguishing different rock types across the area. The total count map revealed the combined effects of the three radioactive elements, whereas the K/Thratio map revealed hydrothermally altered areas, reflecting at the NW-SW, NNE-SSW, SE, central portions and spots at the NE borders. Furthermore, the ternary image map revealed the combined intensities of the radioactive elements and possible hydrothermally altered environments, identified as (AE) on the image map.*

KEYWORDS: Radiometric, Radioactive elements, Intrusive, Hydrothermally altered, Mineralization.

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INTRODUCTION

Radiometric survey involves the measurement of naturally occurring Uranium (eU), Potassium (%K) and Thorium (eTh) which could be found as trace elements that exist in rock forming minerals and soil profiles, thereby decaying to give off gamma radiation (gamma rays). Many naturally occurring elements are known to be radioactive and every detectable gamma radiation from the earth materials comes from the natural decay products of only these three elements Uranium, Thorium and Potassium (Telford et al., 1990). Although many naturally occurring elements have radioactive isotopes, only these three elements (Uranium, Thorium and Potassium) decay series have radioisotopes that produce gamma rays of sufficient energy and intensity, which is measured by a gamma-ray spectrometer during the survey. The radiometric method has been adopted extensively for geological mapping and exploration of other types of economic mineral deposits in many parts of the world. More so, since many rocks are naturally radioactive to some certain degrees the method is very useful in mapping geology by way of distinguishing different rock types and can also assist in identifying intrusive related mineral deposits and potential mineralized zones having known that concentration of rocks is affected by mineralization processes. In radiometric survey, the gamma ray response from the radioelements (K, U and Th) in the rocks can be related to the hydrothermal alterations in the area which can be helpful in detecting areas of metallic deposits or precious metals. The need to investigate and provide useful information about the radiometric anomalies of the study area, which little work has been done, influenced the choice of the present research and attempt will be made to state the results from each of the interpretation and distribution of radioelements and characterize them based on how the anomalies are displayed on maps that may accumulate into the emplacement of minerals deposits.

Location and geology of the study area

The study area is located between latitudes $6^{\circ}00' and\ 6^{\circ}30'\ North$" and longitudes" $7^{\circ}30'\ and\ 8^{\circ}30' East$ within the Lower Benue Trough. It has a coverage area of around 6050 km^2. The thick sedimentary sequence that underpins the Lower Benue Trough can be traced back to the tectonic processes that followed the separation of African and South American plates in the early Cretaceous (Burke, 1996). The Anambra Basin, the Abakaliki Anticlinorium and the Afikpo Syncline are the main component units of the lower Benue Trough. The sequence belongs to the oldest sediment from the Asu River Group, which sits unconformably on top of the Precambrian basement complex that is made up of granitic and magmatic rocks (Ofoegbu & Onuoha, 1991). The Asu River Group displays outcrops in Abakaliki that is Albian in age and has an approximate thickness of about 2 km (Ofoegbu, 1985a). It is made up of argillaceous sandy shales, laminated sandstone units and small limestones with magnetic volcanics, which interfingers (Nwachukwu, 1972). The geological map of the study area is shown in Fig. 1.

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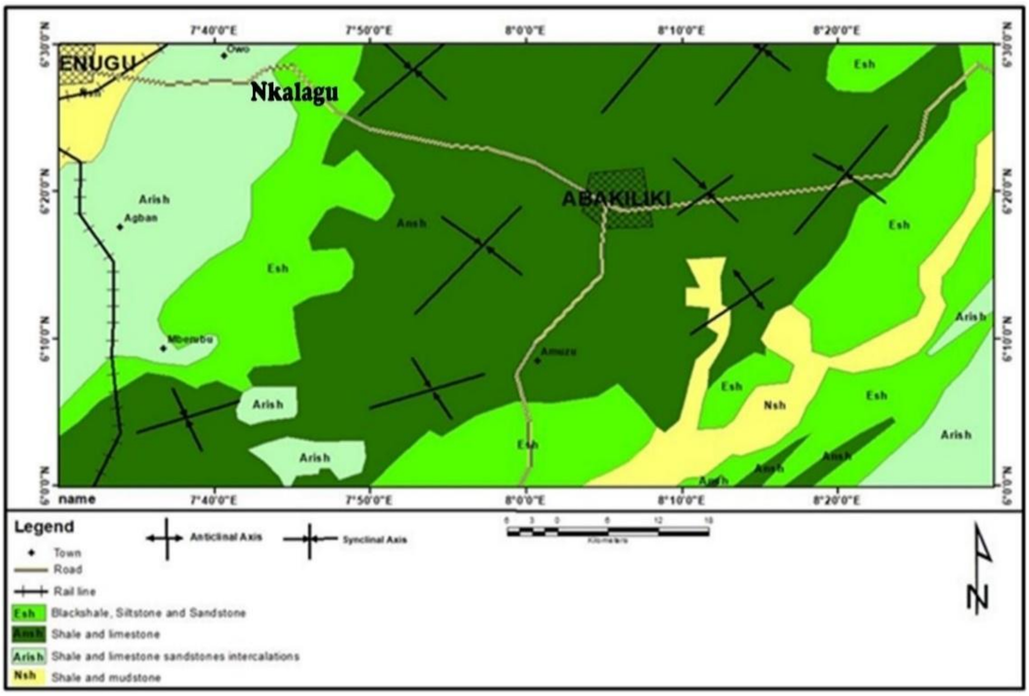

Fig. 1: Geological Map of the Study Area.

MATERIALS AND METHODS OF DATA ANALYSIS

Materials

The materials adopted in the present study are two sheets of aero-radiometric data of Nkalagu (302) and Abakaliki (303), obtained as softcopy digitized data from Nigerian Geological Survey Agency (NGSA) carried out in Nigeria between the years 2005-2009. The data were acquired at a flight altitude of 80m above the ground surface at a tie line spacing of 2km. The flight line spacing is 0.5km and the digital data was made available on a scale of 1:50000. The softwares applications employed for the study are the Oasis Montaj 8.4 and the ArcGis.

Methods of data analysis

The data analysis started with feeding the aero-radiometric data which contain ^{40}K, ^{238}U and ^{232}Th into Oasis Montaj and each of these elements were merged separately using blending method in Grid and Image geosoft extension (GX) to produce each of the three elements (%K, eTh and eU) concentration maps. Thereafter, the total count map containing the combined effects of ^{40}K, ^{238}U and ^{232}Th was also obtained using the blending method in Grid and Image GX. The ternary map was made by assigning colors to each of the element abundances. Potassium as red, thorium as green, and uranium as blue (Millingan & Gunn, 1997) and combining the three radioelements concentration in the RGB colors using Grid and Image GX of Oasis Montaj. The Ratio map that analyzed the individual anomalies in detail was produced using the Grid math expression builder of the Oasis Montaj. This estimated the ratio map of K/Th as expressed in equation (1):

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$$G_0 = \frac{C_1}{C_2} \quad (1)$$

Where G_0 is the total count of the two elements, C_1 is equivalent to element 1 and C_2 is the equivalent of element 2.

RESULTS AND DISCUSSION

Results

Potassium map (%K)

The equivalent Potassium map (Fig. 2) revealed three different levels of K-concentrations that reflect different lithological units in the study area. The first level (low concentration) represented by blue to bright green color ranging from 0.10-0.44 %, is dominant in the north-western (NW) parts of the study area at Owo, Nkalagu, Enugu, Agban & Mbenubu. The second level (intermediate concentration) represented by orange colors ranging from 0.44-0.88 % is associated with chemical sedimentary rocks and the third level (highest concentrations) represented by pink color ranging from 0.88-1.06 %, observed at the central portion (Abakaliki and Amuze), southeastern, northeastern and northwestern directions is associated to mafic intrusive rocks.

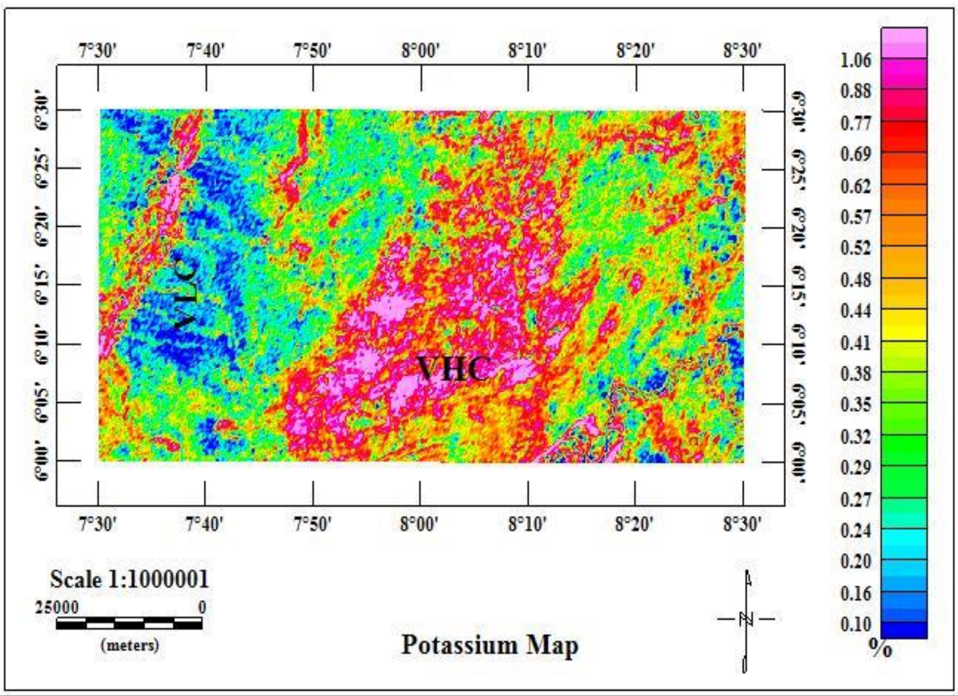

Fig. 2: Equivalent Potassium Map of the Study Area

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Thorium map (eTh)

The Thorium equivalent concentration map (Fig. 3) showed three distinct regions of Thorium concentrations. The study area is characterized by very high concentration (first region) with values ranging from 19.37-21.35p pm and moderately high (second region) ranging from 13.97-19.37 ppm is associated with felsic intrusive rocks while that of the low concentration (third regions) ranging from 5.48-13.97 ppm is associated with felsic extrusive rocks. The high concentration regions are more pronounced at the northern boundaries, central portions and northwestern corners at Enugu and Nkalagu, while the low regions are seen at the western portions at Owo, Agban & Mbenubu.

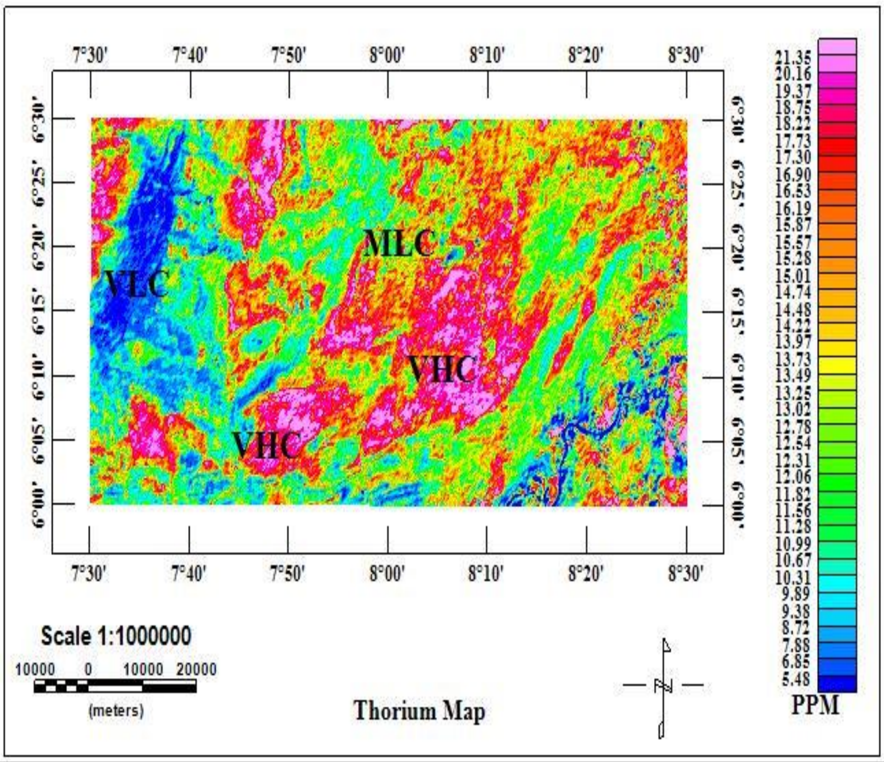

Fig. 3: The Equivalent Thorium Map of the Study Area

Uranium Map (eU)

The equivalent Uranium concentration map (Fig. 4) showed three zones of concentrations. The high concentration zones ranging from 4.97-5.91 ppm (pink colors) is associated with detrital sedimentary rocks and the moderate concentration zones (red shaded with yellow colors), which is ranging from 3.71-4.97 ppm is associated with felsic intrusive rocks. The low concentration zones (blue to bright green colors) spanning from 1.62-3.71 ppm are metamorphosed sedimentary rocks. This classification was done with respect to radioelement concentrations in different classes of rocks (Killeen, 1979).

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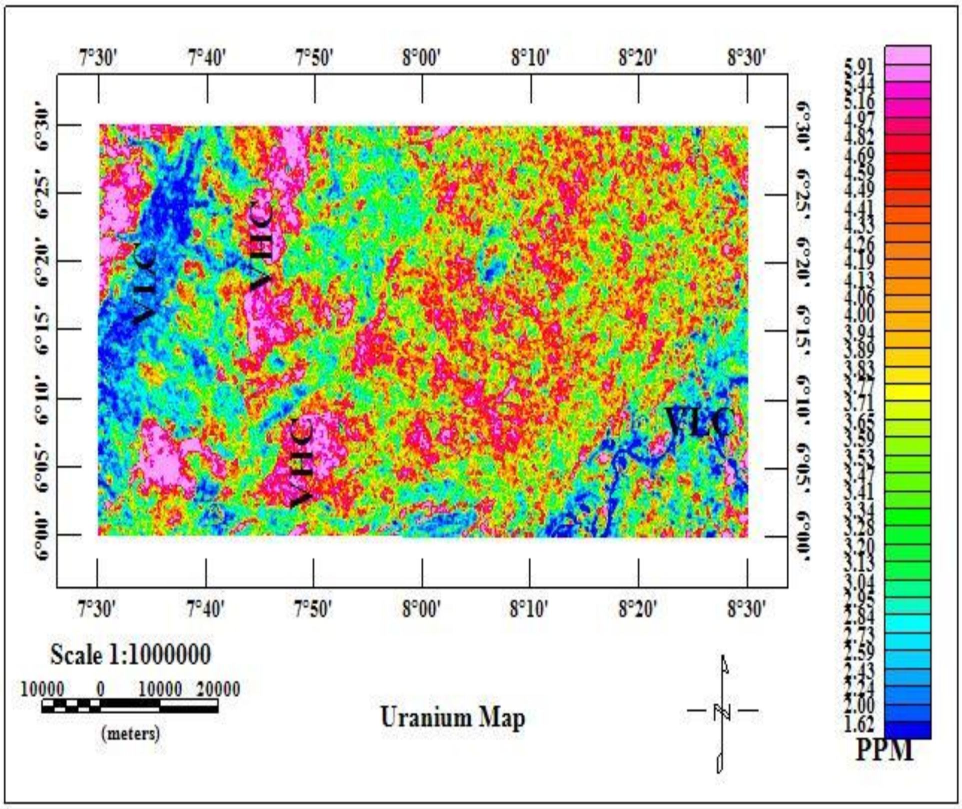

Fig. 4: Equivalent Uranium Map of the Study Area

Total Count (TC) Map

The total count map (Fig. 5) revealed combined effects of the three radioactive elements (%K, eU and eTh) with two major levels of radiation. The combined high concentrations (pink with orange colors) ranging between 5.14-7.59 cpt seen at the central areas (Abakaliki and Amuze), northeastern and spots at the western parts (Enugu). The combined low concentrations (blue to green colors) ranging from 0.55-4.65 cpt observed at the western, northern and southeastern parts. Also, areas like Owo, Agban, Nkalagu and Mbenubu are also seen to have combined low effects.

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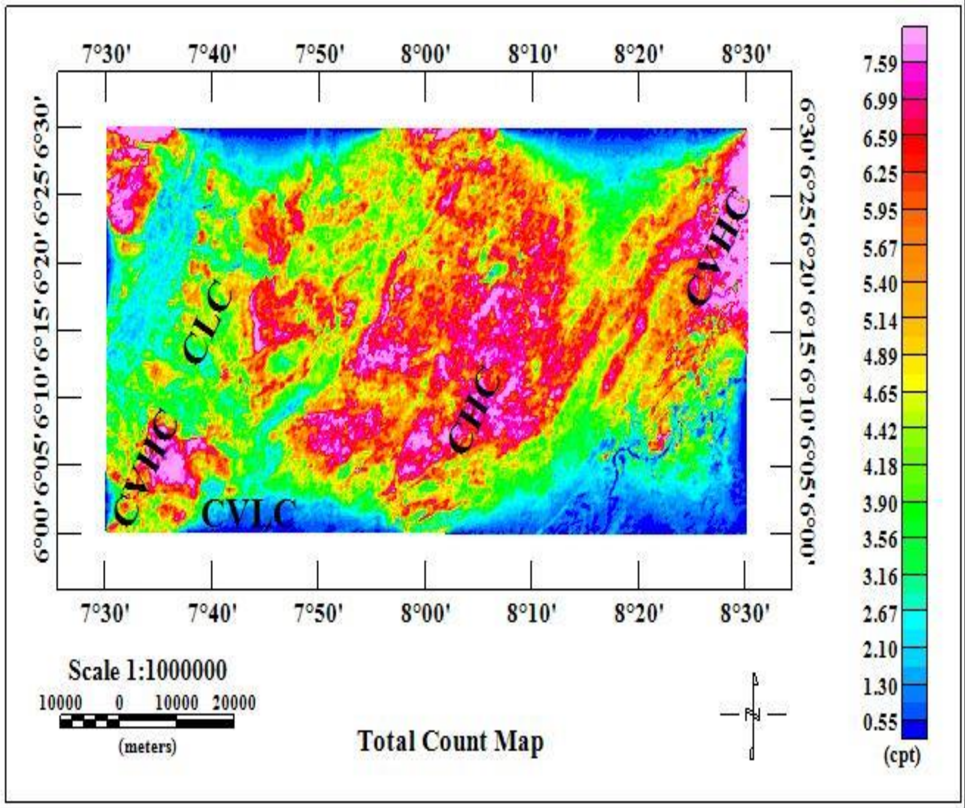

Fig. 5: Total Count (TC) Map of the Study Area

Potassium/Thorium Ratio (K/Th) Map

As Potassium (K) is more mobile than Thorium naturally, K/Th ratio anomalies can be indicative of hydrothermal alterations, which are characterized by enrichment in Potassium (K). It is evident from the K/Th map (Fig. 6) that, the areas characterized by high content of K/Th concentrations (enrichment in K) represented with AE (alteration environment) seen at the NW-SW, NNE- SSW and central portions are strong indicators of hydrothermal altered areas withrange from 0.04-0.07. However, this alteration environments depict areas with accumulation of various ore deposits (Ostrovskiy, 1975), that are found around the area of study. This is because hydrothermal solutions are capable of dissolving and transporting a wide range of metals and salts, which consequently play an important role in ore deposition processes Boamah (1993) and Manu (1993).

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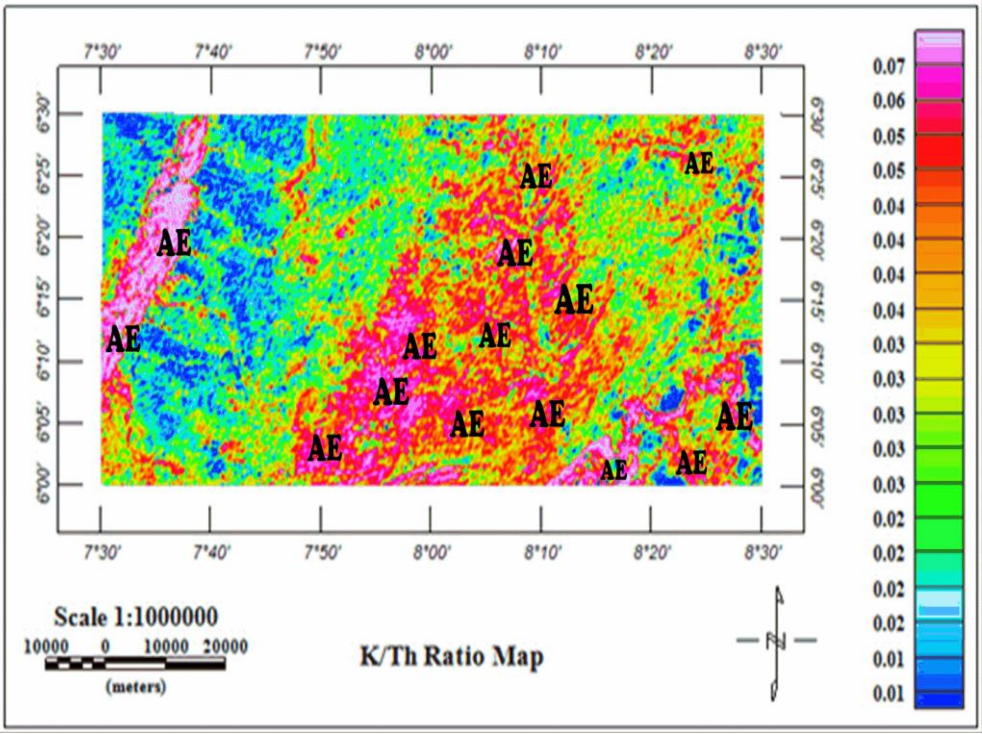

Fig. 6: Equivalent Potassium/Equivalent Thorium Map of the Study Area

The Ternary Map

Ternary map (Fig. 7) revealed combined intensities of Potassium (%K), Thorium (eTh) and Uranium (eU) in red, green and blue respectively. The black color indicates low concentrations of (%K, eTh and eU) seen more at Mbenubu and other parts (Owo and Agban). The red color corresponds to high Potassium, low Uranium and low Thorium concentrations. The high concentrations of Thorium, low concentration of Uranium and Potassium are displayed with green colors. The regions of high Uranium, low Potassium and Thorium concentrations are characterized by blue colors while white color areas are termed regions of high (%K, eTh and eU) concentrations. Additionally, the areas represented with yellow color show regions of high Potassium, Thorium and low Uranium concentration, which depict possible alteration zones as assigned with AE (Alteration Environment). These areas are observed at the NW-SW, NE borders, central portions and SE directions, which closely agree with the K/Th ratio map.

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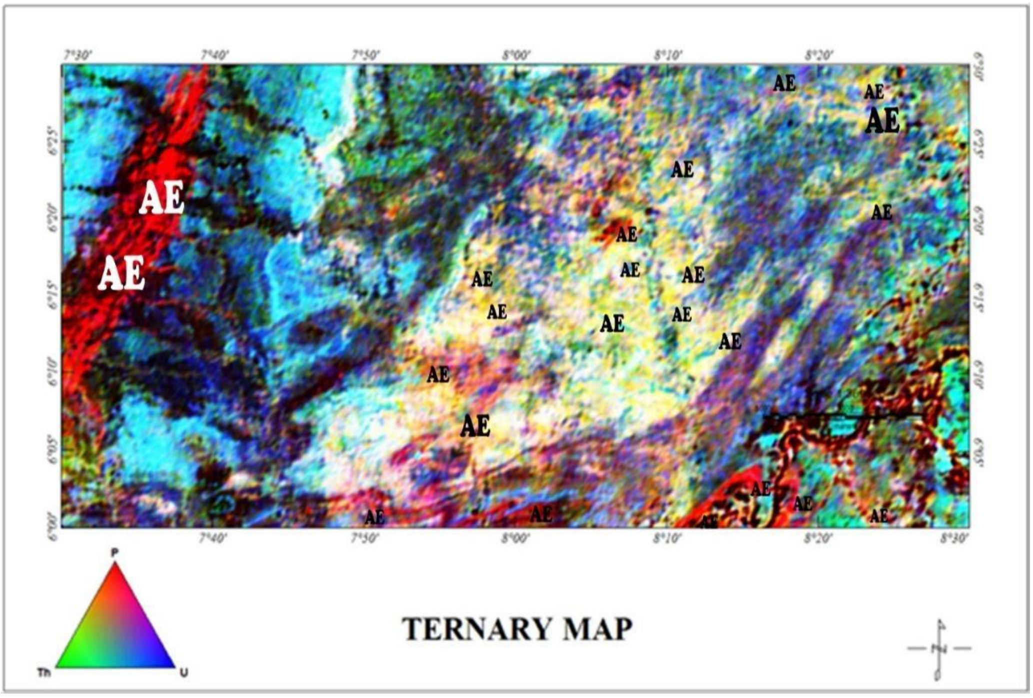

Fig. 7: Ternary Map of the Study Area

DISCUSSION OF RESULTS

The immobile nature of Thorium identified igneous intrusions, which intruded within the area at the time of formation, indicating the presence of felsic intrusive and extrusive rocks of rhyolite and granite. The Potassium retained some sedimentary rock of carbonates, chemical sedimentary rock of limestone and mafic intrusive rock of gabbro while the leaching process of Uranium identified the sedimentary rocks revealed in the geological map of the area, which could be classical sedimentary rocks of sandstone, siltstone, mudstone, shale and felsic intrusive rock of granite and metamorphosed sedimentary rocks of schist and quartzite.

The K/Th map identified areas of alteration environments believed to be spots of accumulated ore deposits, which may be found within the area assigned with (AE) on the image map. The total count map depicts areas where the combined effects of the three radioactive elements are strong within the portions of study while the ternary map identified areas of combined intensities of the three radioactive elements(^{40}K, ^{238}U, ^{235}U and ^{232}Th) in red, blue and green with further identification of areas of possible alteration environments assigned with (AE) on the image map.

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CONCLUSION

The radiometric data, productively assisted in mapping hydrothermal altered zones, types of intrusive bodies and portions were the combined effects of the three radioactive elements are strong. The possible alteration environments suggested by the ratio map of Th/K and the ternary map aligned in the NW-SW, NNE- SSW and central portions are host areas of mineral accumulation spots, which could aid exploration of base metal mineralization. Furthermore, the intrusions delineated from the present study closely agree with the types of intrusions delineated by other researchers who have worked in the area using magnetic methods. These intrusions, by implication, can destroy hydrocarbons, because the presence of numerous intrusions are an indication of exceedingly high temperature history (Ugwu & Ezema, 2012).

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