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ASSESSMENT OF RADIOELEMENT HOSTING STRUCTURE AND HYDROTHERMAL ALTERATION ZONE USING AERO RADIOMETRIC DATA IN BASEMENT ROCK OF NORTH CENTRAL NIGERIA

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ABSTRACT

Natural gamma-ray spectrometry data of Sheet 145 of the Nigeria Geological map series in Basement rock of North Central Nigeria were used in this work to map-out radioelement distribution, delineate hydrothermal alteration zones and identify hosting rocks for the radioelement. Radioelement maps, ratio maps, and ternary maps were produced superimposed on the geology map of the study area using Oasis Montaj and ArcGIS software. The spatial distribution and occurrence of Potassium (K), Thorium (Th) and Uranium (U), were determined using the radioelement maps of Potassium (K in %), equivalent Thorium (eTh in ppm) and equivalent Uranium (eU in ppm). The hydrothermal alteration zones were delineated using the percentage potassium (% K) - equivalent Thorium (eTh) ratio (K/eTh) map. Zones of high concentrations on the map was delineated as the alterration zones. The ternary map for (K, eTh and eU) were generated to delineate areas of different radioelement concentration. Different colors on the ternary map correspond closely with different rock types when compared with the geological map.

Keywords: Radioelements, gamma ray, radiometric, lithology and ternary map

INTRODUCTION

The radiometric or gamma-ray spectrometric method is a geophysical method used in geology, geomorphology and minerals exploration. It is used in the mapping for radioactive mineral reserves needed for nuclear energy, and also for non-radioactive reserves related with radioactive elements. The method produces exceptional radioactive results in the mapping of the various kinds of geological formations (Wilford, 1995; Kearey et al., 2002; Milsom, 2003). The most useful of these radiations in radiometric survey are gamma-rays' radiations. The gamma-rays are packets of electromagnetic radiation characterized by their high frequency and energy. They are quite penetrating and can travel about 35 centimeters through rock and several hundred meters height through the air (Minty, 1997). Each gamma ray has a characteristic energy, and measurement of this energy allows the specific potassium (K), thorium (Th) and uranium (U) radiation to be diagnosed (Billings et al., 2003, Grasty et al., 1979). Darnley and Ford (1989) mentioned that gamma-ray spectrometry is probably more relevant than any other single airborne geophysical method in providing information directly interpretable in terms of surface geology. All rocks and soils contain radioactive isotopes, and almost all the gamma-rays detected near the earth's surface are the result of the natural radioactive decay of potassium (K), thorium (Th) and uranium (U). Airborne gamma-ray

spectrometric surveys estimate the concentrations of the radioelements at the earth's surface by measuring the gamma radiation above the ground from low-flying aircraft or helicopters. Aero radiometric has found useful application in measuring the abundance of Potassium (%K), Thorium (eTh) and Uranium (eU) in rocks and weathered materials obtained from the emission due to the natural radioelement decay of these elements (Silva et. al., 1999). Dickson and Scott (1997) added that aside from geological mapping, airborne spectrometry had shown increased potential to detect alteration in the radioelement as a result of mineralization. The performance of radioelement during weathering depends on the initial bedrock composition and their response depends on mineralogy and bedrock chemistry due to deposit from different materials (Darnley and Ford, 1989). The basic purpose of this work is to delineate possible radioelements hosting structure and hydrothermal alteration within Sheet 145 of the Nigerian Geological map series in Basement rock of North Central Nigeria.

STUDY AREA AND GEOLOGY

Sheet 145 is a geological survey of Nigeria geologic map series which lies within the Nigerian basement complex located in kajuru local government area of Kaduna state. It is located between longitudes $10^{0}00^{l}$ North and $10^{0}30^{l}$ North and latitudes $7^{0}30^{l}$East and $8^{0}00^{l}$East with an area of 2,464km^{2}. The general relief of the area is fairly plain with isolated rock outcrops of inselbergs found in the area thus creating undulations in the area. The inselbergs are granitic in origin formed from under laid basement complex rocks. The area is a part of the extension plains of the northern Nigeria. The area lies within the northern section of the Nigerian geological provinces, which composed of Precambrian Basement Complex rocks. The major rock types in the study area (Fig. 1) include the gneisses (porphyroblastic, granitic and banded gneisses), biotite granites (porphyritic and medium to coarse grained varieties). The rocks also include a schist formation and comprises of mica schist interbedded with quartzite, tourmaline-quartz rocks and amphibolites rocks. Elsewhere schist occurs as relicts within the granite. Other metamorphic rocks include gneisses, migmatites which cover about 65% of the area and hornfelses (Udo, 1973).

According to Food and Agricultural Organization (FAO), the area is made up of ferruginous tropical soil which is derived from intensive weathering and granitization of the basement which are mostly migmatite, gneiss, granite and schist. These soils are generally well drained and mostly sandy- loam and loamy soil in plains while in the valley there are deposits of hydromorphic soils, which occupy the flood plains of the rivers. The soils in the area are rich in mineral content and therefore support the high agricultural productivity in the area.

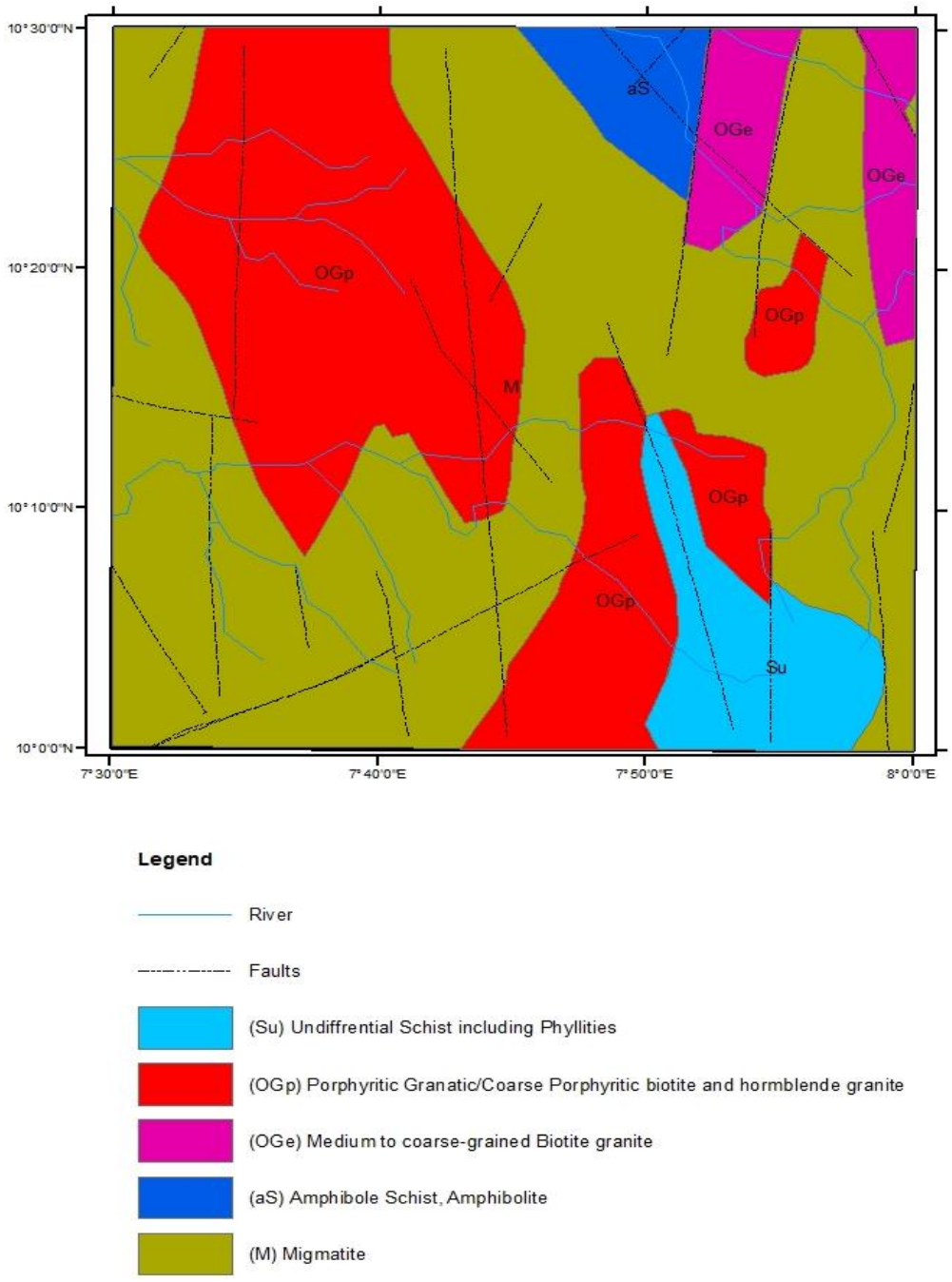


Fig 1 Geology map of the study area

MATERIAL AND METHOD

The aero radiometric data used in this work was obtained from Nigeria Geological Survey Agency (NGSA) in form of corrected digital map. The data were collected above the ground by flying an airplane with a spectrometer for regional surveys. Gamma rays arising from the decaying of unstable nuclei from the rocks are recorded in the radiometric survey. The airborne radiometric technique is efficient in the identification of only the existence of potassium (%K), thorium (Th) and uranium (U) at the Earth's surface (Urquhart, 2003). Oasis Montaj and ArcGIS software were used to create a concentration map representing the horizontal variation of radioactive elements associated to the surface geology of the study area. Concentration maps

of Potassium (K in %), equivalent Thorium (eTh in ppm) and equivalent Uranium (eU in ppm) were produced. Furthermore, radioelement ratio and ternary maps were generated to delineate Potassium enrichment zones as indicators of potential mineral resource-related alteration zones.

RESULT AND DISCUSSION

Figure 2 represent a combine potassium (%K) concentration map overlaid with the geologic map to help map-out the boundary of anomaly source rock. The potassium (%K) depicts different degree of concentration ranging from -0.085 to 8.214 % that reflects the different lithological units in the study area. High signatures seen in the eastern, central towards the south eastern flank of the map. These are attributed to granitoid rock; due to its high level of K-feldspar. These areas associated with coarse grained prophyrittic biotite and humbled granite,

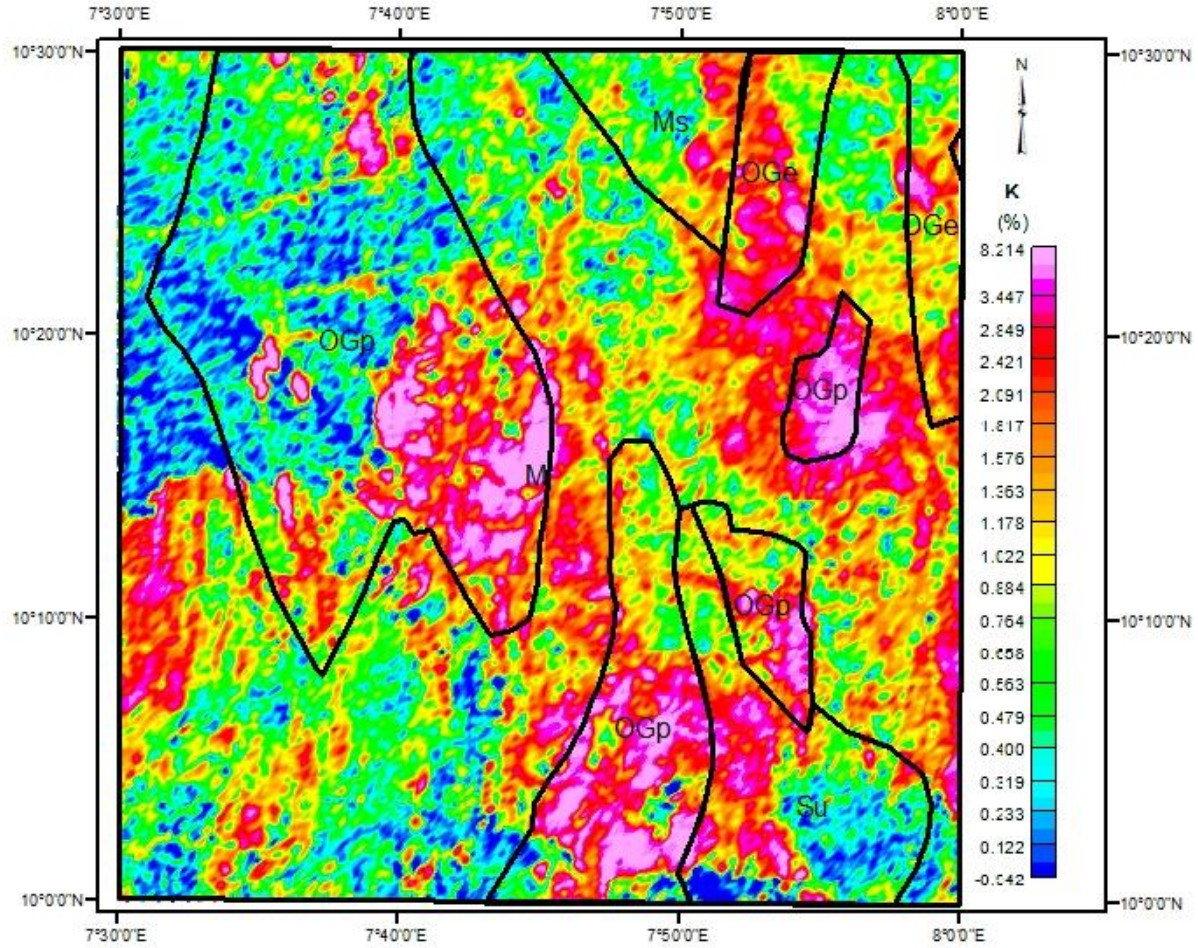


Fig 2 Potassium (%K) concentration map of the study area

In addition to potassium concentration maps, a K/eTh ratio was calculated to highlight locations with higher Potassium content (Figure 3). As potassium is more mobile than thorium, K/eTh ratio anomalies may reveal possible areas of hydrothermal alteration which are characterized by K enrichment. High concentrations of this element may reveal possible areas of hydrothermal alteration and mineralization (Abd El-Nabi, 2013; Sheves et. al., 2000). The K/eTh ratio is often considered the best indicator of Potassium enrichment zones related to hydrothermal alteration (Tawey et al., 2021). K/eTh ratio is nearly constant in most

rocks, typically ranging from 0.17 to 0.20 (K/Th in %/ppm) (Hover and Pierce, 1990). Rocks with K/eTh ratios remarkably outside of this range could be due to hydrothermal alteration processes associated with the emplacement of magmatic-hydrothermal mineralization (Portnov, 1987). From figure 3, it is seen that areas affected by hydrothermal process are featured by pink colour and marked. In this present study the hydrothermal alteration zones fall within the medium to coarse-grained biotite granite and part of the undifferentiated schist.

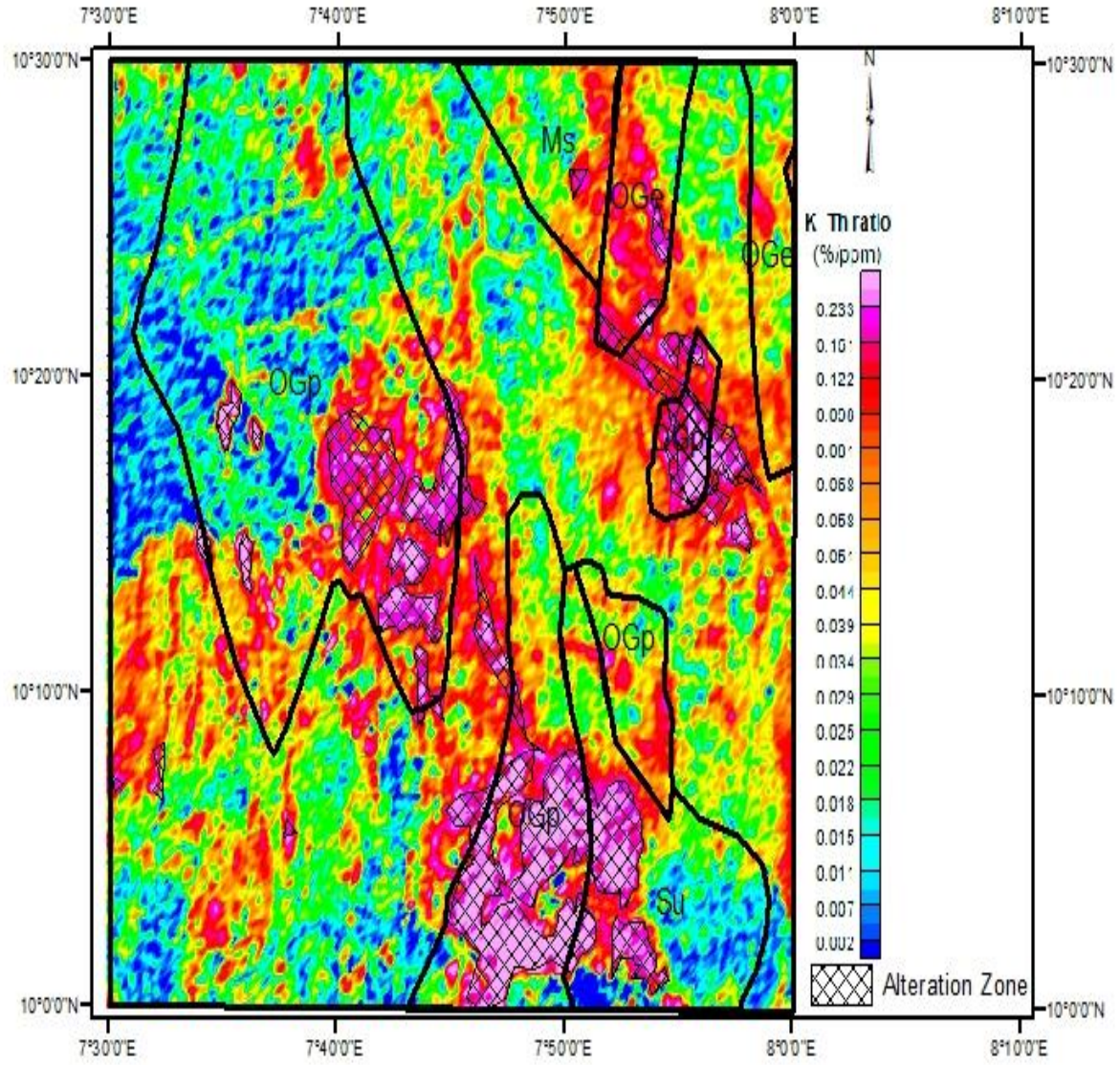


Fig 3 K/Th Ratio map of the study area

Thorium generally is not affected by alteration processes because it is typically immobile in mineralization processes or it can only partly be depleted in areas of intense K-alteration and silicification (Tawey et al., 2021). Figure 4 displays the eTh distribution map with an overlaid geology of the study area. The eTh distribution map has eTh concentration ranging from 4.327 to 115.819 ppm. Areas of high eTh concentrations is mostly associated with the migmatite rocks and part of the coarse grained porphyriticgranite.

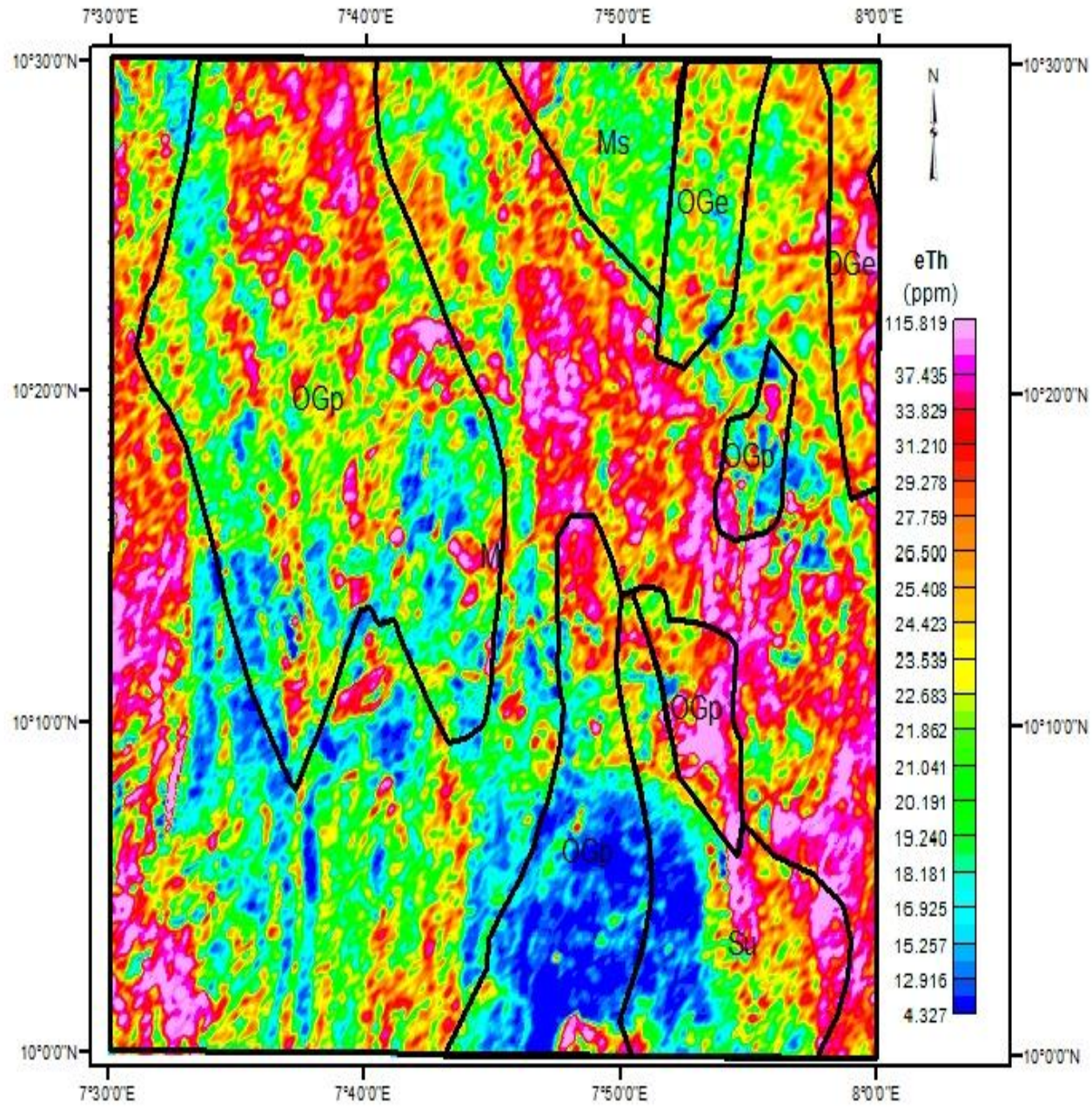


Fig 4 Thorium (eTh) concentration map of the study area.

Figure 5 displays the eU concentration map with the geology map impose on it. According to Airo, (2007), uranium is a very mobile element in hydrothermal and other geological processes; an enrichment of uranium may or may not be accompanied by an enrichment of potassium. The map shows various anomalous signatures with total eU that looks like the eTh map. The concentrations of eU map varying between -2.051 ppm to 27.786 ppm. High eU concentrations are attributed to the migmatite and the coarsed grained porphyritic and biotite granite.

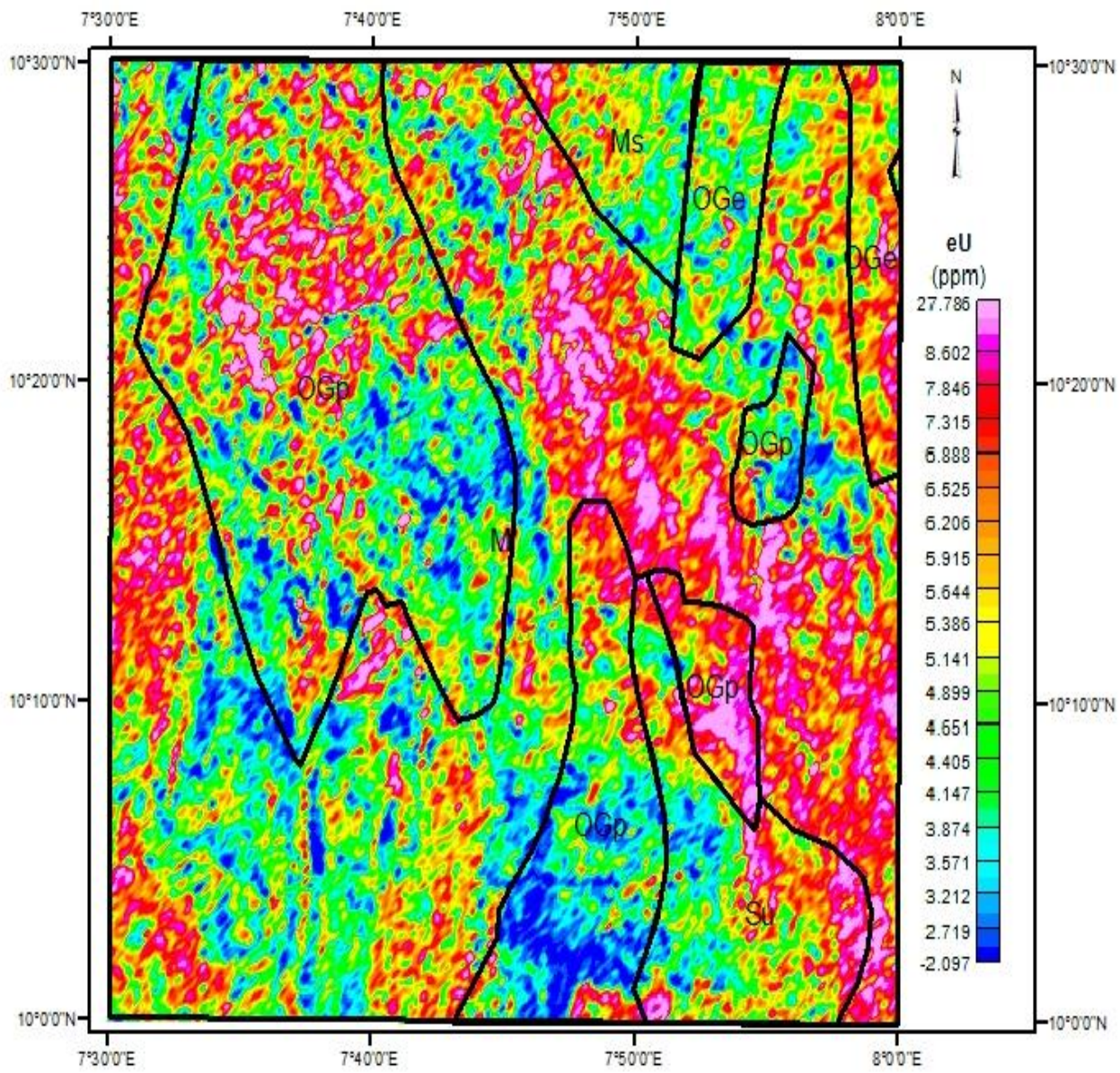


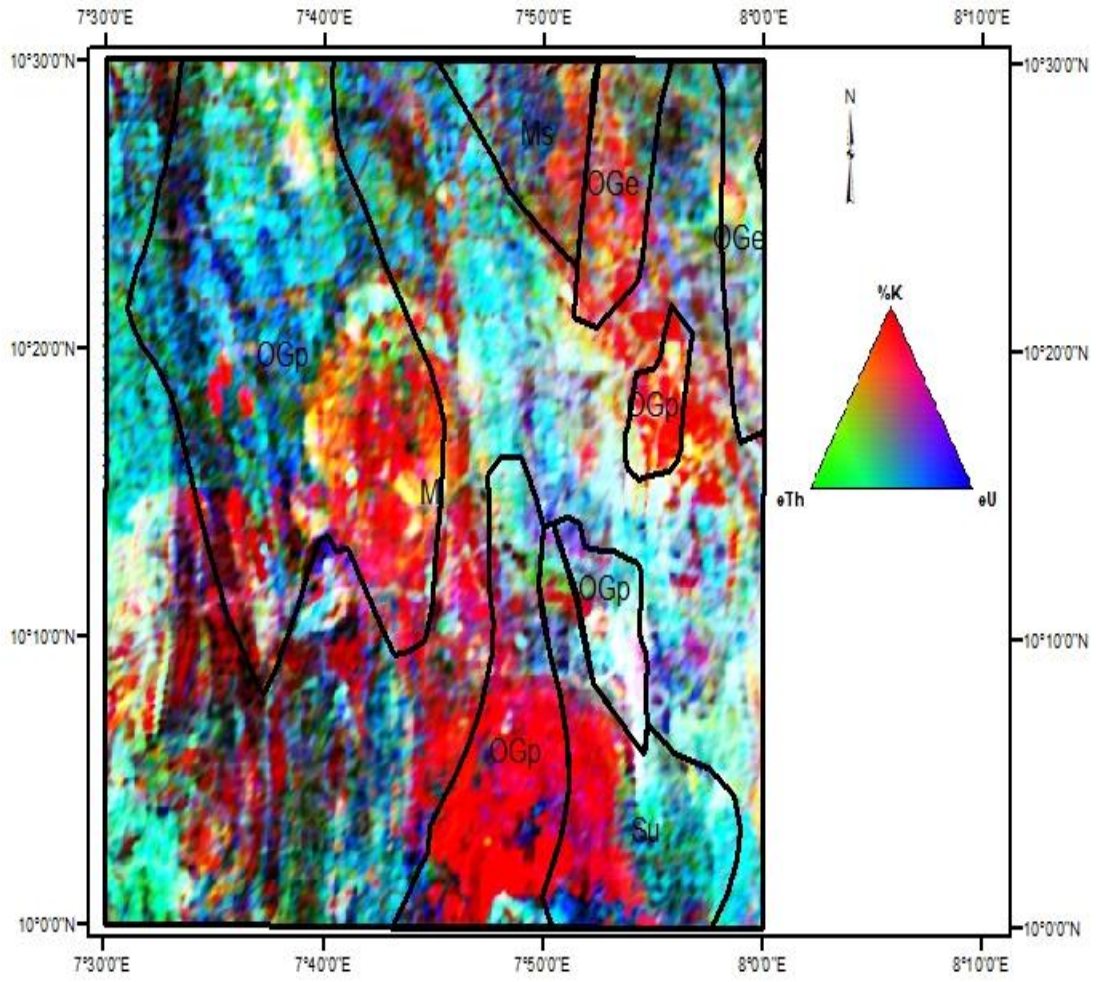
Fig 5 Uranium (eU) concentration map of the study area.

TERNARY MAP

A RGB ternary map was produced (Fig. 6a) while (Fig. 6b) is the CMY ternary map produced to compliment the RGB ternary map for geological mapping which in turn found to be very useful for anomaly discrimination. Bright red zones on the RGB ternary map show zones of high potassium count rate, bright green indicates zones of high thorium count rate and the bright blue are areas where the uranium count rate is very high relative to both of the other elements count rates. Colors other than the three primary colors indicate zones with various well-defined proportions of K, Th and U. Cyan zones are high in Th and U with in low K. Magenta zones are high in K and U with low in K. Yellow zones are high in K and Th with low U. White zones are made up of high K, Th and U while black zones have low K, Th and U concentration.

The CMY ternary radiometric map shows different colour combinations which indicate the K, Th and U concentrations. The intensities of potassium (K), thorium (Th), uranium (U) concentration is given in cyan, magenta and yellow colour respectively.

Generally, the different colors on the ternary map correspond closely with different rock types when compared with the geological map. According to Dickson and Scott, (1997) the distribution of radioactive elements concentration in soil and rocks relate to the differences in lithology of common rocks, alteration and metamorphism processes. From the RGB ternary map, we can decipher the following colors: white (High K, Th and U) zones which are associated with exposed granitic bedrock and sediments derived from granite. These are very much discriminated on the CMY map as all those rocks are now showing dark (black) color. These zones are associated with the coarsed grained biotite, the migmatite and schist. These zones represent promising targets for radioactive minerals exploration. Black to brown (Low in K, Th and U) zones is associated with migmatite. Cyan (high Th and U) are observed in the fine-grained leucocrate granite, coarse grained porphyritic and Migmatite. Magenta color (high K and U) is associated migmatite and fine-grained coarse rocks. High K and Th are identified by the yellow color and this is associated with pelvic schist ans migmatite. Red zones are associated with an increase in the K concentration. Green zones are associated with an increase in the Th concentration. Blue zones are associated with an increase in the U concentration. The host rocks for these elements are clearly discriminated in their concentration maps.



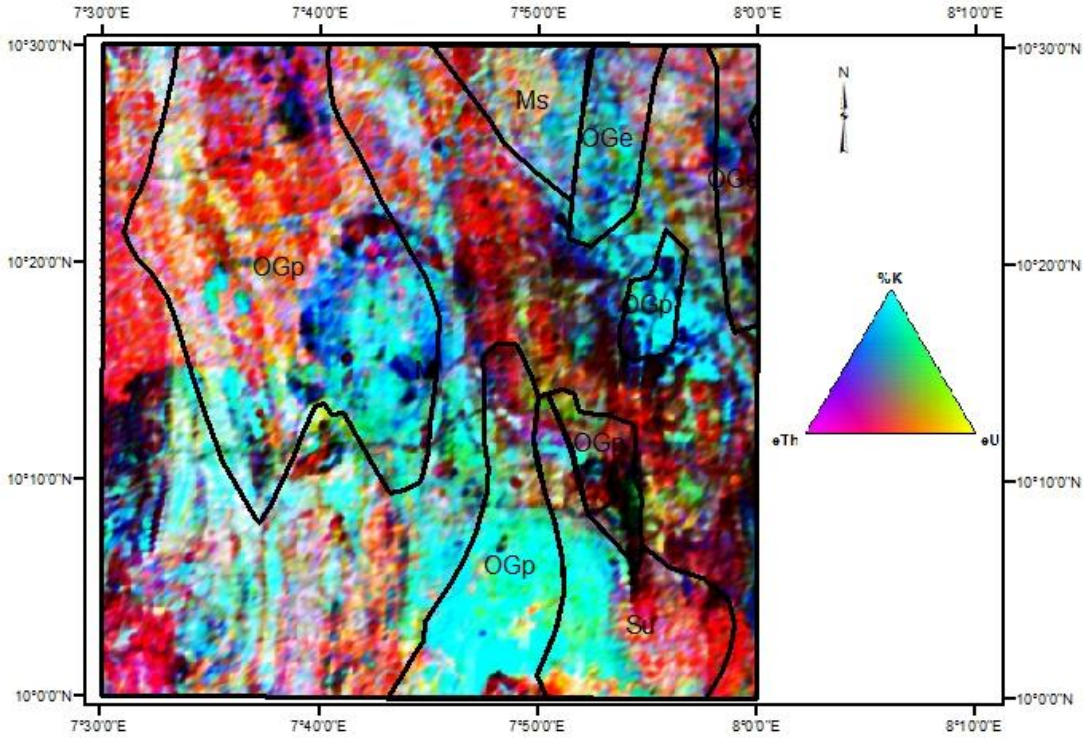


Fig. 6 Ternary map of the study area

CONCLUSION

Gamma rays arising from the decaying of unstable nuclei from the rocks are recorded in the radiometric survey.

The entire noticeable gamma radiation from rock minerals occurring from the natural breaking down of three radioactive elements which are potassium (K), thorium (Th) and uranium (U) were recorded using the airborne radiometric survey. The airborne radiometric technique is efficient in the identification of the existence of potassium (%K), thorium (Th) and uranium (U) at the Earth's surface. Concentration maps of Potassium (K in %), equivalent Thorium (eTh in ppm) and equivalent Uranium (eU in ppm) were produced to represent the horizontal variation of radioactive concentration associated to the surface geology of the study area. Furthermore, radioelement ratio and ternary maps were generated to delineate the high concentrations of radioactive elements related to the altered zones, particularly in Potassium and to identify the spatial variation of the radioelements in the study area. Zones characterized by the high K/eTh ratio values that are the strong indicator of hydrothermal alteration have been delineated (Figs. 3). These are areas associated with granitoids and part of the undifferentiated schist.

The different colors on the ternary map correspond closely with different rock types when compared with the geological map. This colour composite images have been used to delineate the concentration of different radioelements in relation to the surface geologic of the study area (Fig. 6) since particular rock types often have characteristic ratios of the three radioactive elements, the ternary maps of these ratios are useful geological and mineral exploration tool for discriminating the zones of consistent lithology and contacts between contrasting lithology (Duval 1983).

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