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Delineation of Geologic Units, Mineral Potentials and Distribution in Udegi Complex and Environs, North Central Nigeria, Using Airborne Radiometric Data

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Abstract:
***Background**: Udegi Area, Nasarawa State, Nigeria is fast becoming an important study area for geoscientists in view of increased efforts to explore the geological structures within it. Many locations within the place are known for illegal mining, leading to huge loss of revenue to the country. Nigeria lacks adequate control over the illegal mining and does not guard some affected areas because the government lacks adequate knowledge of the locations of most of the structures with potentials of hosting mineralization within the area. Hence, the geological mapping of the area, with the aim to define the lithology, boundary and distribution of the rock types and delineate the alteration zones favourable for mineralization within the place was undertaken.*
***Materials and Methods**: High resolution airborne radiometric data over Udegi Complex and environs were used and the processed data were gridded to generate the concentration maps of percentage Potassium, equivalent Thorium and Uranium, the abundance ratios and the ternary images of the three radioactive elements.*
***Results**: Six geological rock units which predominantly have NE-SW trend and characterised by structural deformations were delineated. The alluvia within the Complex were delineated to have average thorium-potassium ratio of about 10.6 ppm/% and most likely host minerals such as thorite, uraninite and uranothorite.*
***Conclusion:** The radioactive signature mapped thermal alteration zones and two major types of deposits within the area. The first is hydrothermal alteration associated with sulphide mineralization within the mafic to ultramafic metavolcanic rocks and the second is associated with disseminated and vein deposit of cassiterite and its associate minerals at the apex of the biotite granite rocks of the Udegi Complex.*
***Key Word**: Udegi Complex, Geologic Mapping, Hydrothermal Alteration, Sulphide Mineralization, Vein Deposit of Cassiterite.*

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I. Introduction

Radiometric survey is carried out with a gamma-ray spectrometry, with the aim of measuring the distribution of naturally occurring radioelements (Potassium, Thorium and Uranium). During the weathering of rocks, the relative proportions of K, Th and U are reflected in the soil (Shi and Butt 2004); therefore, these measurements can be used to map and characterise different lithological/rock units as there is a notable variation in the concentration of radioelements between different rocks (Graham 1993 and Jaques et al. 1997). According to Darnley et al. (1989), radiometric method records a high success in mapping surface geology than other geophysical methods. There is also a good correlation between interpreted radiometric data and un-weathered rocks; therefore, the amount and proportion of K, Th and U which are emitted from the surface can be useful in mapping soil properties and regolith (Gunn et al. 1997). Hence, the distribution of radioactive elements such as Potassium (K), Thorium (Th) and Uranium (U) concentration in soil and rocks relate to the differences in lithology of common rocks, alteration and metamorphism processes (Dickson and Scott 1997; Brempong et al. 2019). The concentration of these radioactive elements is therefore used in geologic mapping, as different rock types can be recognized from their distinctive radioactive signatures (Moxham 1963). Many authors (Shives et al. 1997; Nigm and Khameis 2009; Amadi et al. 2012; Wemegah et al. 2015; Patra et al. 2016; Nwokeabia et al, 2018; Sayed and Mahmoud, 2019) have tried to remap lithological units by using this technique. Shives et al. (1997) also showed that the method is best in highlighting thermally altered rocks (alteration), especially with the use of Th/K ratio for potassic alteration mapping. These alteration zones are favourable zones for mineralization and should be looked for in exploration.

The study area, Udegi is located in Nasarawa State, North Central Nigeria. Nasarawa State is endowed with abundant mineral resources like no other State in Nigeria. The three major geological components that make up the geology of Nigeria, namely, Basement Complex, Younger Granites and Sedimentary Rocks are all exposed in Nasarawa State. All known minerals that occur in Nigerian Geological environments are present in the state. At present, the area is fast becoming an important study area for geoscientists in view of increased efforts to explore structural features within it. Unfortunately, the place lacks adequate information on the geological structures underlying it. Many locations within the place are known for illegal mining, where unauthorized people use obsolete methods in mining the minerals the state is endowed with. This has led to huge loss of revenue to the state and the country. Nigeria lacks adequate control over the illegal mining and does not guard the affected areas because the government lacks adequate knowledge of the locations of most of the structures with potentials of hosting mineralization within the area. This study applied high resolution airborne radiometric data, in the geological mapping of the study area, with the aim to define the lithology, boundary and distribution of the rock types and delineate the alteration zones favourable for mineralization within the place. The results and recommendations of this study will guide Nigerian government in mapping out the places that require adequate security as means to control illegal mining which characterises the area.

There has been no major geophysical study of the Udegi Complex and its environs. The studies carried out in the area are usually geochemical explorations by mining companies targeting cassiterite deposit and these methods are very expensive. This research looks to provide a concept for reconnaissance exploration for mapping geology and ore target region to provide a cost-effective exploration approach.

II. The Study Area

The study area is located in the North Central part of Nigeria. It is bounded by Latitudes 8.00 °N and 8.30 °N and Longitudes 7.30 °E and 8.00 °E. It covers a total surface area of about 3,025 km^2. The area is located within the southern part of Nasarawa State, and the major towns within it include Udegi, Bakare, Loko and Zangwan Daji. Figure 1 shows the Accessibility Map of the study area. The area is mainly occupied by basement rocks of relatively high rugged mountains with many prominent peaks (e.g. Udegi Complex), mostly made of volcanic and granitic rocks. These rocks are flanked by cretaceous sedimentary rock of the Central Benue Trough at the south and its terrain appears to be less rugged.

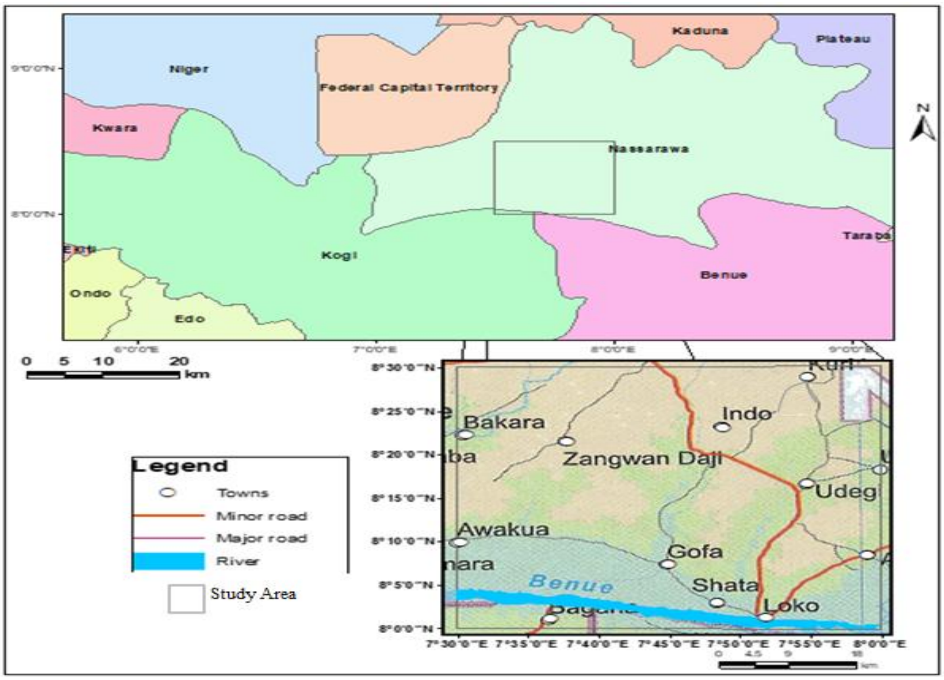

Figure 1. Accessibility Map of the Study Area.

The elevation of the study area (Figure. 2) ranges from about 50.4 m to 357 m above mean sea level. The place has low land in the southern part and high land at its northern part. The highlands have a NE-SW trend with an average height of about 155 m above mean sea level. About eighty percent of the entire study area is in the highland range. The highest point within the study area is the famous Udegi Complex. The altitude in the lowland zone ranges from about 50.4 m to 80.2 m above mean sea level. This lowland zone in the study area is occupied by sediments of the Central Benue Trough.

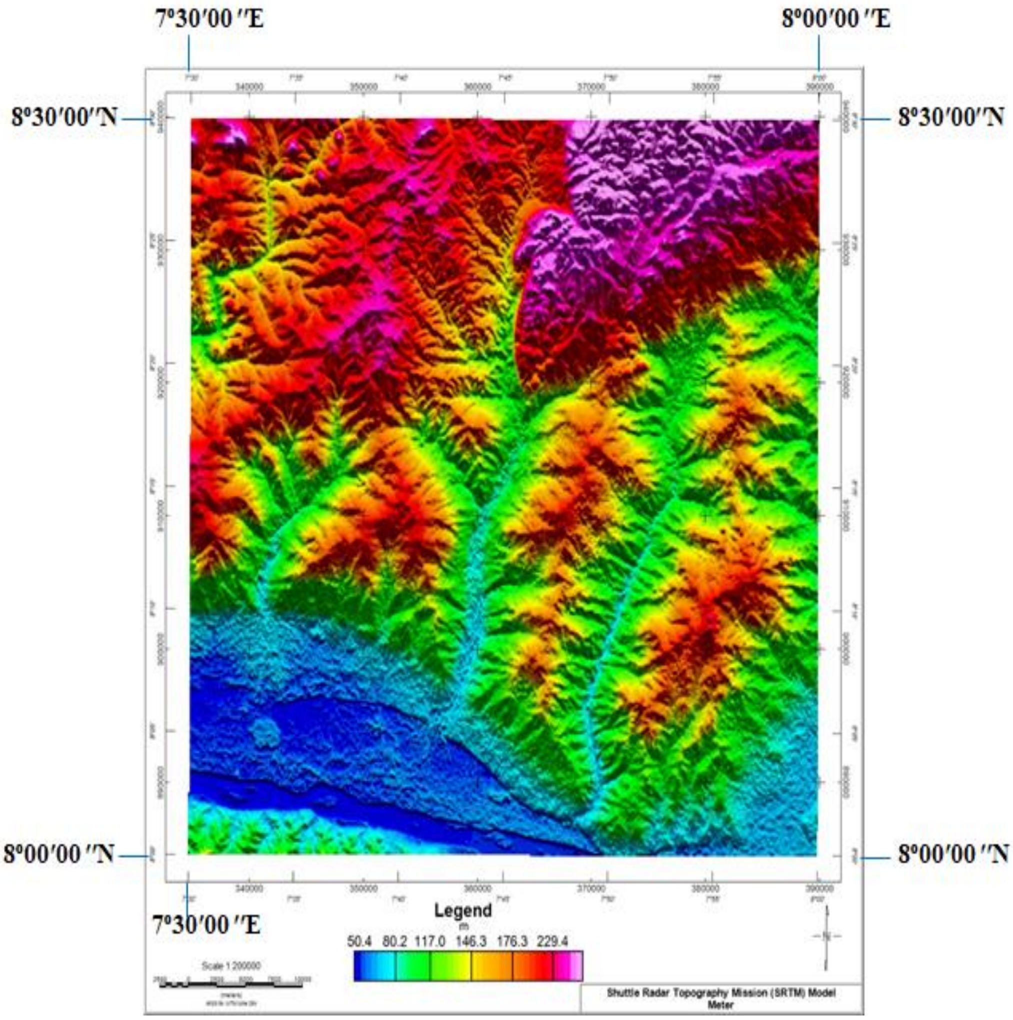

Figure 2. Digital Elevation Map (DEM) of the Study Area.

III. Geologic Setting

The Geology Map of the study area is presented in Figure 3. The area predominantly falls within the Basement Complex of Nigeria; it is part of an Upper Proterozoic to Lower Phanerozoic Mobile Belt situated between West African and Congo Craton. The belt is believed to have evolved by plate tectonic process which resulted from continental collision between the passive Continental Margin of the Tuaraep Shield (Burke and Deway 1972; Black 1980). The rocks of the basement complex have been subdivided by Oyawoye (1972) and Woakes et al. (1987). Geologically, the study area is underlain by metasedimentary rocks (migmatite, gneiss, schist and quartzites) and these metasedimentary rocks have been intruded by granitic rocks (Older and Younger Granite Suite). The rock types constitute the major Basement Complex rocks as defined by Oyawoye (1972) and Woakes et al. (1987). The granite rocks are well exposed in outcrop, while the metasedimentary rocks are majorly exposed at road cuts and quarries.

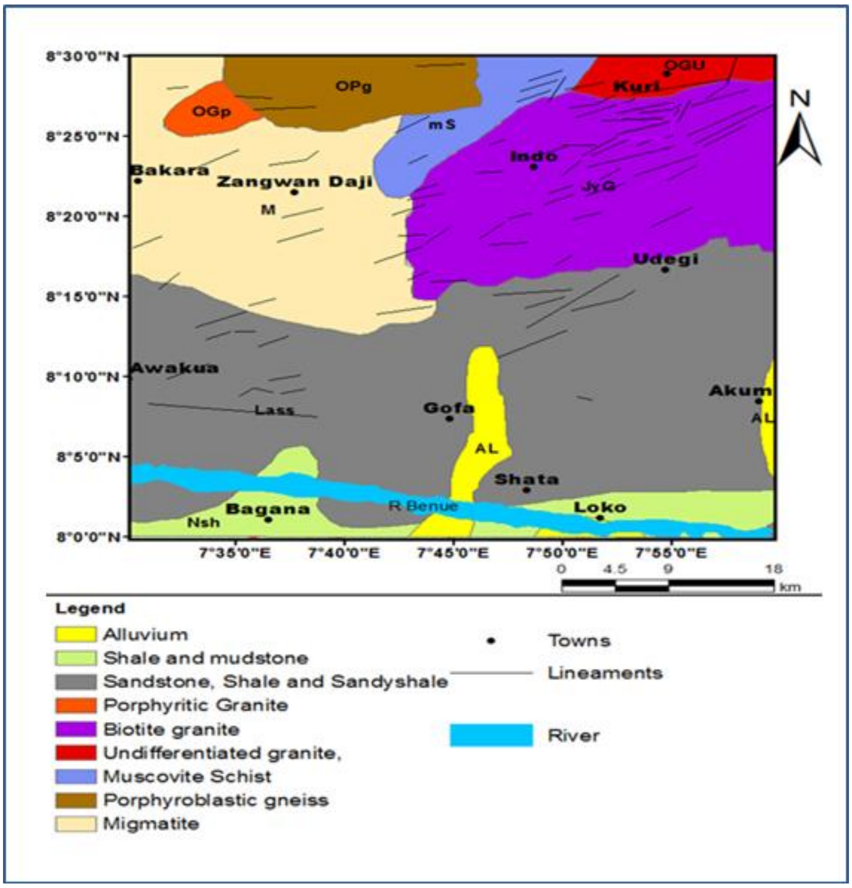

Figure 3. Geology Map of the Study Area.

IV. The Airborne Radiometric Data, Materials and Methods

The airborne radiometric data used for this study were acquired by Fugro Airborne Survey and Nigerian Geological Survey Agency. The data were acquired along NW – SE flight lines at 500 m line spacing, 20 km tie lines spacing and at 80 m terrain clearance. The study area is covered by one airborne radiometric dataset, Index Sheet Udegi-229. The index sheet covers an estimated area of about 3,025 kilometer square. The parameters measured were the radiations emitted from Potassium (K) in %, Uranium (U) and Thorium (Th) in ppm. The preliminary data processing was accomplished using Geosoft (Oasis Montaj, version 8.4) software and the data were micro-levelled for the removal of residual errors and noise. The radio-elements' concentration grids were developed by employing a minimum curvature algorithm at 100 m grid cell size. The data enhancement techniques employed led to the generation of potassium (%K), equivalent thorium (eTh ppm) and equivalent uranium (eU ppm) maps as well as the ratio maps and composite images of the three radioactive elements. In this study the ternary map was created with the grid displayed in Geosoft by assigning potassium with red colour, thorium with green colour and uranium with blue colour. The ternary map showed the concentration of the elements relative to one another. Arc GIS software was used for map integration and digitization of interpreted lithology and structures.

V. Result and Discussion

Figure 4 is the % K concentration map of the study area and it shows Hp1 as region of high potassium activity. This high potassium count at the region suggests that Hp1 could be of granitic rocks with rich potash content, since granitic rocks normally contain high potassium activity (ICRU 1994). Moderate potassium activity region (Mp1) is also found in the Central Benue Trough sediment zone, and this is most likely as a result of carbonates and sandstones with occasional shales in minute amount (ICRU 1994).

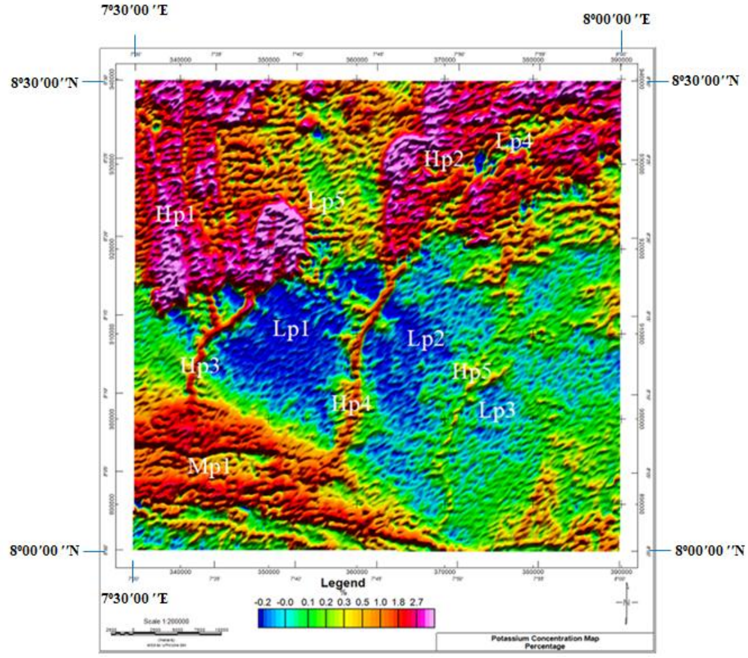

Figure 4. Map of Potassium Concentration (%) in the Study Area.

Lp1, Lp2 and Lp3 are regions with low potassium activity; these regions have the lowest potassium count rates in the study area and are found in the volcanics of the Central Basement Complex of Nigeria. Low potassium count or activity in these regions is associated with mafic and ultra-mafic volcanic rock units such as diorite (andesitic) and gabbro (basaltic).

High potassium activity in the northeastern part of the study area (Hp2) lies in the Udegi Complex which is composed of distinctive biotite granite rocks and geologically underwent sodic metasomatism, yielding oxide ores, principally columbite and cassiterite disseminated throughout the apical zones. In the northeast central and neighbourhood of Hp2, is a moderate to low potassium signature zone (Lp4); this is interpreted as area of thick alluvial accumulation.

The K concentration map was superimposed on the topography map of the study area and the result of the superimposition is presented in Figure 5. Some linear structures (Hp3, Hp4 and Hp5) with NE-SW trend and with high potassium activity were delineated. The structures most likely were formed along potential drainage pathway into the sedimentary basin at the southern part of the study area.

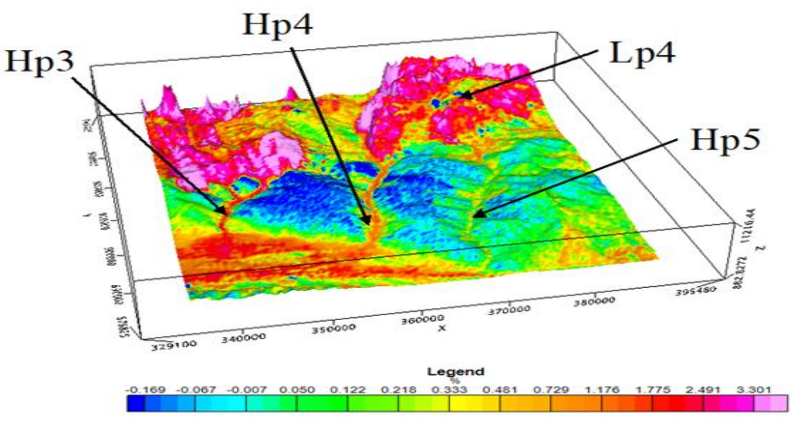

Figure 5. Map of Potassium Concentration (%) in the Study Area with Topographic Constrain.

Figure 6 is the eTh concentration grid for the study area and it shows Hp1 and Hp2 to have high concentration of thorium that coincides with high concentration of potassium. High concentration of both thorium and potassium at Hp1 and Hp2 further suggests that the zones are predominantly biotite granite rock with high concentration of thorite. This mineral is closely associated with cassiterite and columbite in the North Central Basement Complex of Nigeria. Mp1 Zone has moderate amount of potassium and thorium concentration; this signature most likely resulted from sedimentary rocks (sandstone and shale).

Lp1, Lp2 and Lp3 have very low to moderate thorium count and the boundaries between them are well defined in the thorium map (Figure 6) and with NE-SW trend. These regions lie in the volcanics and also recorded very low potassium count in Figure 4. These characteristics of Lp1, Lp2 and Lp3 suggest that the regions are made of mafic to ultra-mafic metavolcanic rock units, since mafic volcanic rocks generally lack thorium and potassium activities. The NE-SW trending high potassium concentration structures (Hp3, Hp4 and Hp5) in Figures 4 and 5 also show high thorium concentration. These are most likely due to accumulation of weathered alluvium along drainage paths at the contacts between the Basement Complex and Central Benue Trough (lowland) at the southern end of the study area.

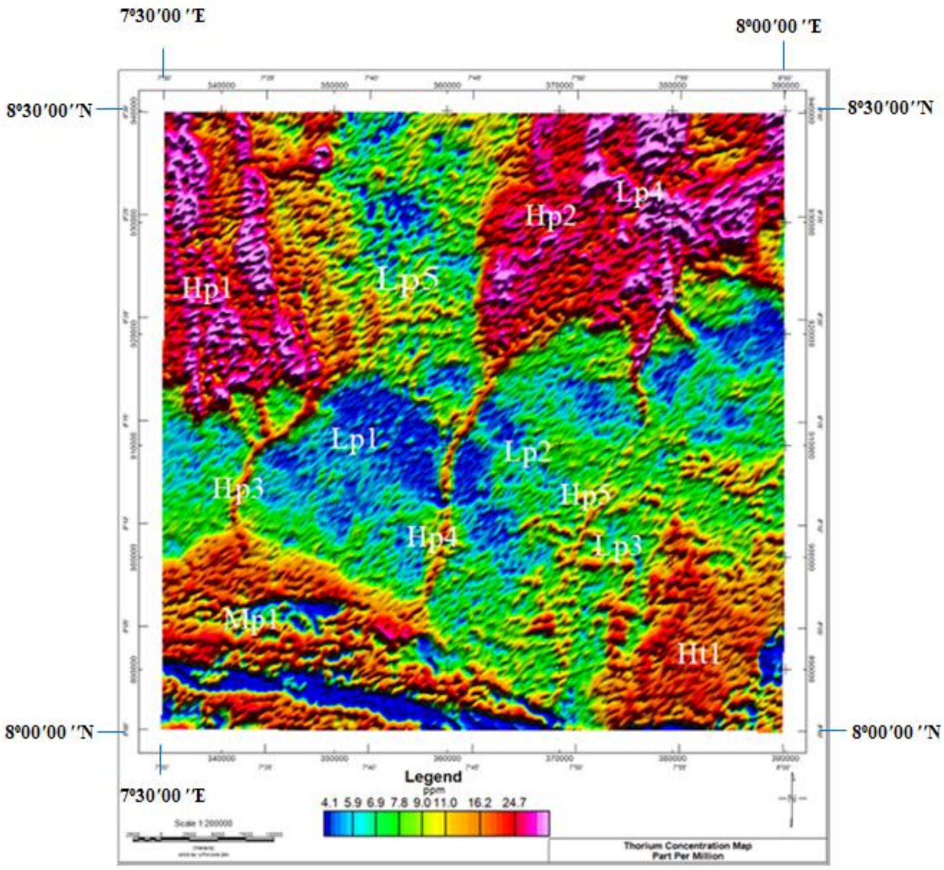

Figure 6. Map of Thorium (eTh) Concentration (ppm) in the Study Area.

The central part of the Udegi Complex (Lp4), which recorded moderate to low potassium signature, has high thorium concentration. This is most likely due to the accumulation of thorite within the alluvium. Ht1 is a region of high thorium concentration and low potassium concentration; this region is predominantly associated with volcanic rocks. High thorium concentration is associated with minerals such as pegmatites, zircon, monazite, allanite, sphene apatite and xenotime, and these minerals are concentrated in metavolcanic rocks (Kearey et al. 2006). This further suggests that Ht1 zone is predominantly rich in aforelisted minerals and are most likely granite gneiss with high thorium content.

The thorium concentration map was superimposed on the topography map of the area and the resultant presented in Figure 7. A zone, P1 was mapped which is indicative of accumulation of thorium minerals within alluvium at the bottom of a slope (basement complex – sedimentary basin contact).

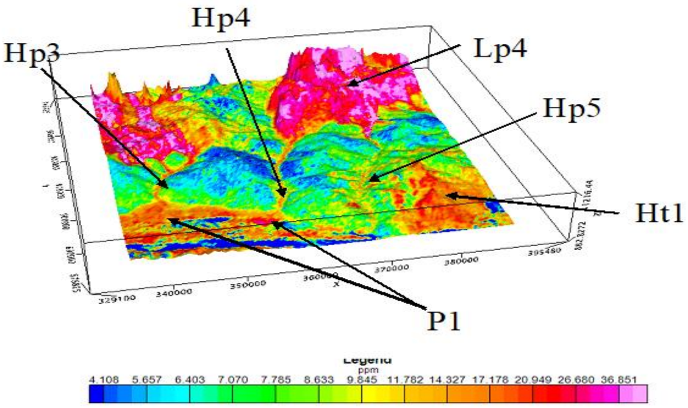

Figure 7. Map of Thorium (eTh) Concentration (ppm) in the Study Area with Topographic Constrain.

Figure 8 is the eU concentration grid for the study area; the figure shows that Hp1 and Hp2 regions have high uranium activity. These regions had shown high activities in potassium (Figure 4) and thorium (Figure 6). These suggest felsic intrusions within metasedimentary environment in those regions. Also, the high uranium, thorium and potassium activities in Hp1 further suggests that Hp1 is a biotite granite rock with minerals such as uraninite, thorite and uranothorite. Mp1 region shows moderate to low uranium concentration; it also shows moderate to low thorium activity (Figure 6) and high potassium concentration (Figure 4). These further suggest that the major sedimentary unit within the basin (Mp1 region) is shale, since shale contains high amount of potassium and tends to absorb uranium and thorium as part of its clay content; the areas with low thorium and uranium account for areas with carbonates. Uranium concentration at Ht1 zone is very high. This suggests later stage of magmatic differentiation of igneous formation in the region.

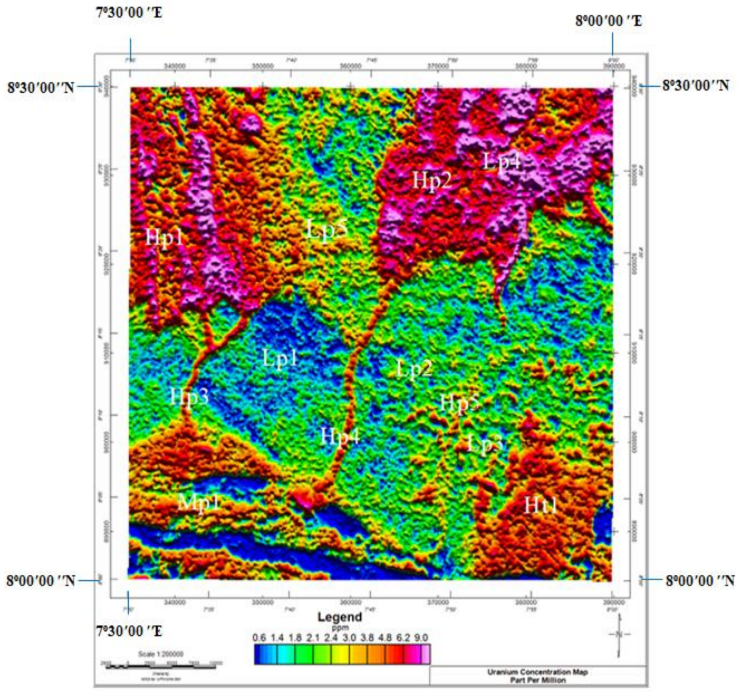

Figure 8. Map of Uranium (eU) Concentration (ppm) in the Study Area.

Lp1, Lp2 and Lp3 Regions have low uranium concentration which is associated with mafic to ultra-mafic volcanic units. High concentration of uranium and thorium at Ht1, coupled with the moderate to low concentration of potassium at the region suggest that Ht1 could contain minerals such as pegmatite, quartz, and monzonite in a meta-volcanic rock. High uranium concentration at Ht1 Region is further suggesting that the zone is predominantly a gneiss rock type. The P1 Zone interpreted to host thorium minerals within the alluvium, is also observed to host uranium minerals which is indicated by high uranium concentration in the constrained uranium concentration on topography map (Figure 9).

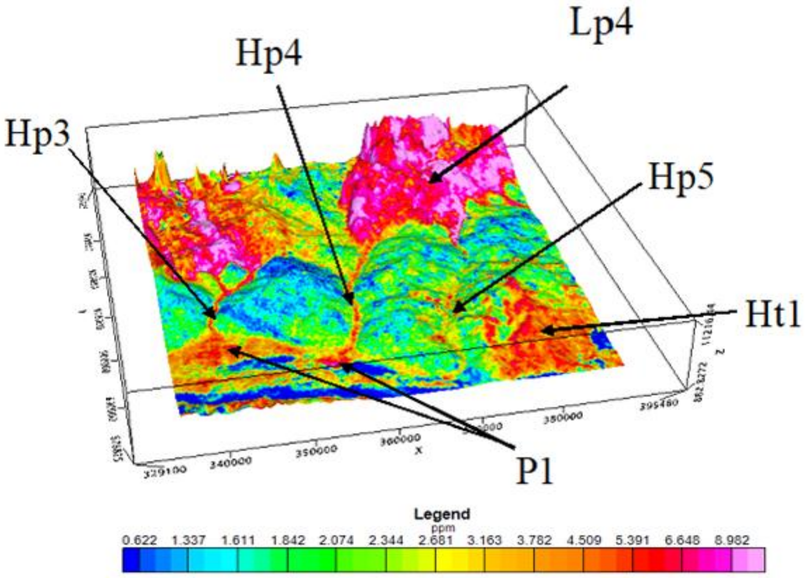

Figure 9. Map of Uranium (eU) Concentration (ppm) in the Study Area with Topographic Constrain.

The Abundance Ratios, eTh/K, eU/K and the Ternary Map of the Study Area

Urquhart (2013) had observed that the abundance ratios are often more diagnostic of changes in rock types, alteration, or depositional environment than the values of the radio-isotope abundances themselves, which are subject to wide variations due to soil cover. The effect of environmental factors on radiometric response, such as soil moisture, vegetation, and topography, are less evident on band ratios. The ratios therefore often correlate more with geological units. This is visible as thermal alterations leads to the enrichment of one radioactive element at the expense of the other (Schwarzer and Adams, 1973; Lundien, 1967). Also, since there is usually a high correlation between bands, the ratios often show subtle features that are not apparent on the original grids. The radio-isotope abundances used for the analysis of both geologic units and rock alteration in this study are eTh/K and eU/K.

The Thorium-Potassium Ratio (eTh/K) Map

Generally, thorium is not affected by alteration processes because it is typically immobile in mineralization processes. It can only partly be depleted in areas of intense K-alteration and silicification. The ratio, K/Th is therefore a better indicator of thermal alteration than any single radioelement alone. The concentration of soil clay and silt are also characterised by thorium and Th/K (Schwarzer and Adams 1973; Lundien 1967). The eTh/K map for the study Area (Figure 10) shows that the features marked Lp1, Lp2 and Lp3 have very low values (< -4.4 ppm/%) of the ratio. The formations (Lp1, Lp2 and Lp3) were delineated to show very low potassium count (Figure 4). These suggested that the structures are made of mafic volcanic units. Very low eTh/K values associated with the Lp1, Lp2 and Lp3 structures (Figure 10) strongly suggested an enrichment of potassium in the areas and this is a strong indication of thermal alterations in the zones. Zones Lp4 and Lp5 record high thorium (Figure 6) and eTh/K (Figure 10), and moderate to low potassium (Figure 4); these are indicative of alluvium with high amount of thorite.

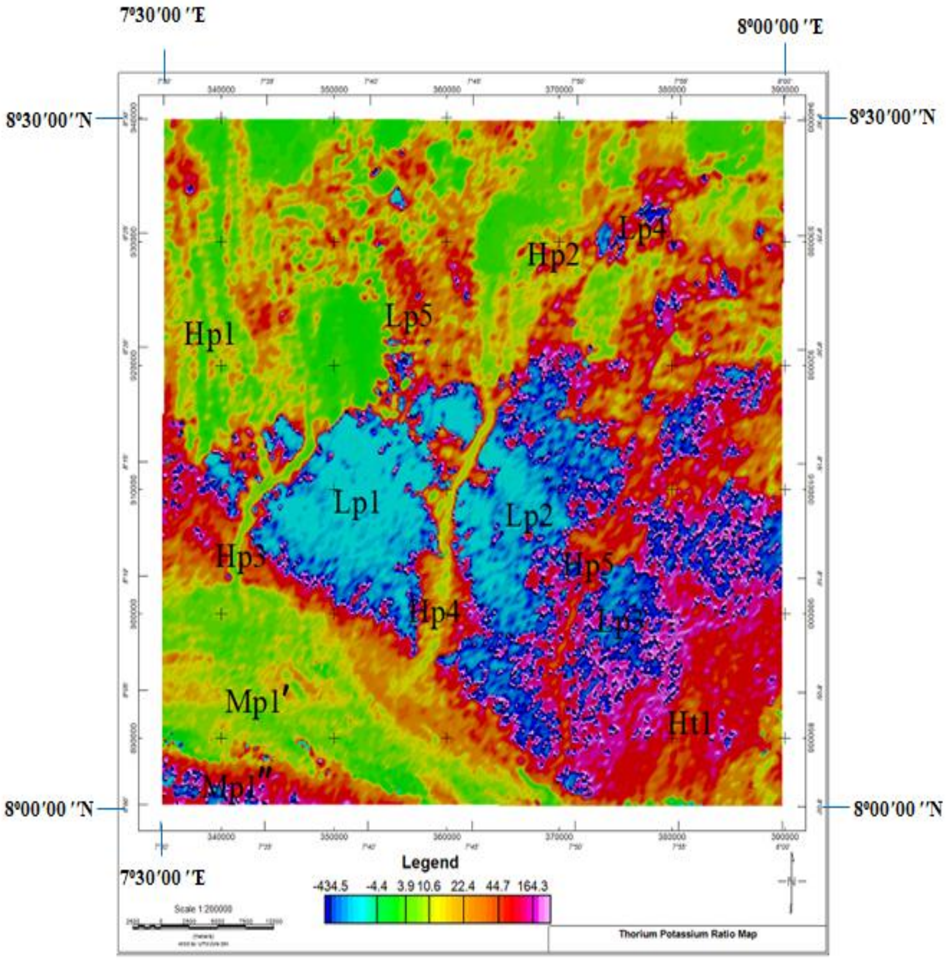

Figure 10. The eTh-K Ratio Map for the Study Area.

The rock units in Hp3, Hp4 and Hp5 (Figure 10) have eTh/K average of about 10.6 ppm/% which suggests that potassium and thorium concentrations are almost in equilibrium. This suggests that alluvium weathered from the highlands and accumulates along the valley which serves as a drainage partway within the study area. In the K, eTh and eU concentration maps (Figures 4, 6 and 8 respectively) Hp1 and Hp2 zones showed high concentration of all the elements. Average eTh/K of 3.9 ppm/ % at Hp1, Hp2 and Mp1 zones may suggest high concentration of minerals such as thorite and uranothorite at the apex of the rock unit; however, high concentration of all the elements at the zones suggests that no thermal alteration took place in them.

Ht1 zone has high eTh/K average of about 44.7 ppm/% (Figure 10). This high ratio, alongside high concentration of thorium (Figure 6) and low concentration of potassium (Figure 4) in the zone strongly suggest that no alteration occurred at the place.

The Uranium-Potassium Ratio (eU/K) Map

Uranium is a very mobile element in thermal and other geological processes; an enrichment of uranium may or not be accompanied with an enrichment of potassium. The ratio, U/K is therefore not a good indicator in identifying mineralization. Notwithstanding, U-K ratios are indicative of concentration of minerals such as uraninite and uranothorite, which are all associate minerals of cassiterite in the North Central Basement Complex. Figure 11 is the eU-K ratio map for the study area. It shows Hp1 and Hp2 as zones of moderate to low eU-K ratios and this is suggestive of granitic rocks (Biotite granite).

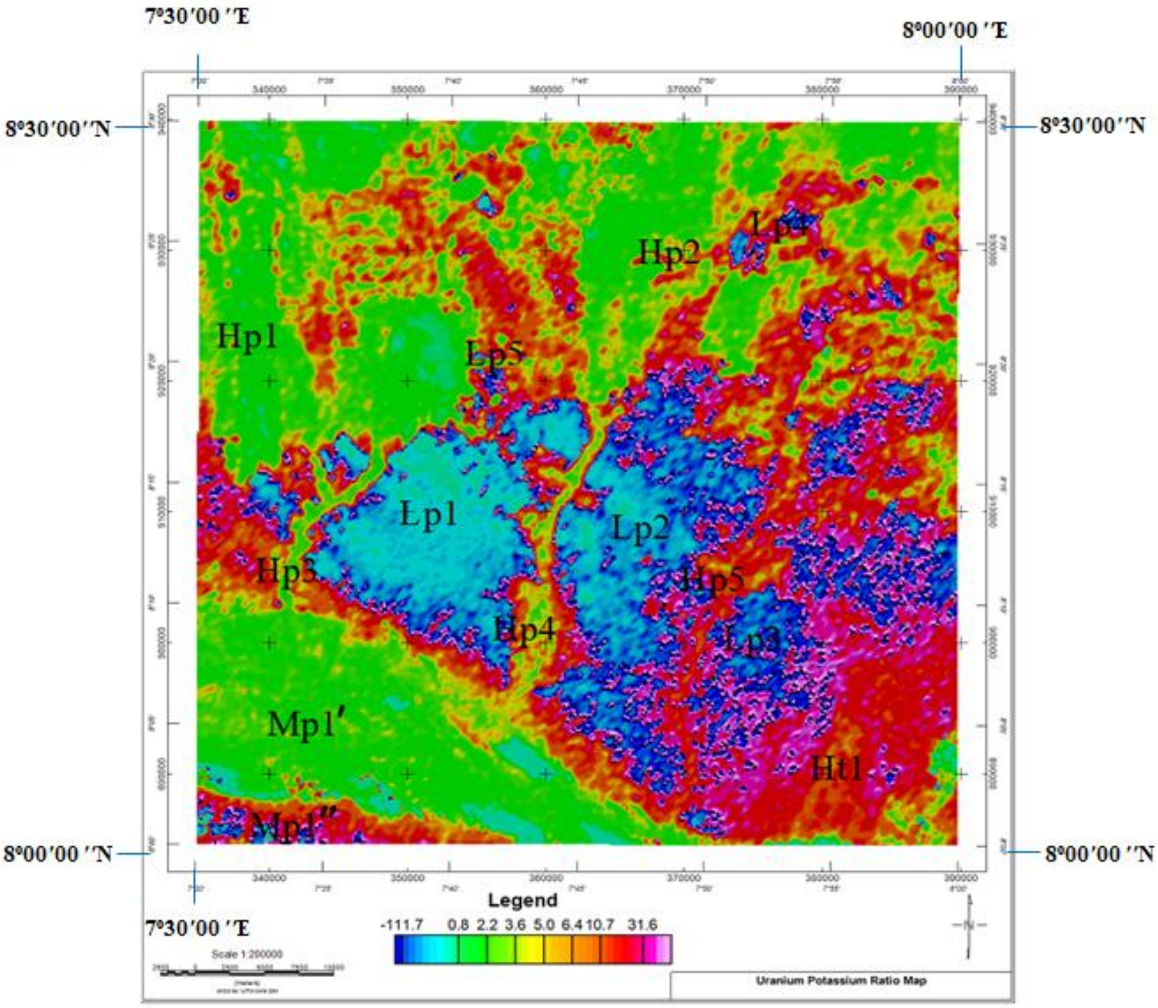

Figure 11. The eU-K Ratio Map for the Study Area.

Zones Lp4 and Lp5 are characterised by high eU/K values (Figure 11); the zones also recorded high eTh-K ratio, thorium and uranium concentrations and moderate to low potassium activity. These are indicative of alluvium with rich thorite, uranothorite and uraninite in the zones. The regions, Lp1, Lp2 and Lp3 have also recorded low eU-K ratios which suggest that the zones have very low uranium count compared to potassium in the regions. This could be an indication of potassium enrichment in the regions. The eU/K map (Figure 11) and eTh/K map (Figure 10) show Mp1′ and Mp1′′ as sub-regions of Mp1 indicating sedimentary units with moderate to low and high values of the Abundance Ratios respectively. Mp1′ is interpreted as sandstone unit while Mp1′′ is interpreted as shale and carbonate rock unit.

The Ternary Map for the Study Area

Figure 12 is the ternary map of all the three radioactive elements in the area and it shows that Hp1 and Hp2 zones have high concentrations of eU, K and eTh depicted by the white colour. Since this occurred in the Udegi Complex which is characterised by biotite granite rocks, high concentrations of all the three radioactive elements are linked with rholitic volcanic rocks that are associated with biotite granite rock within the area.

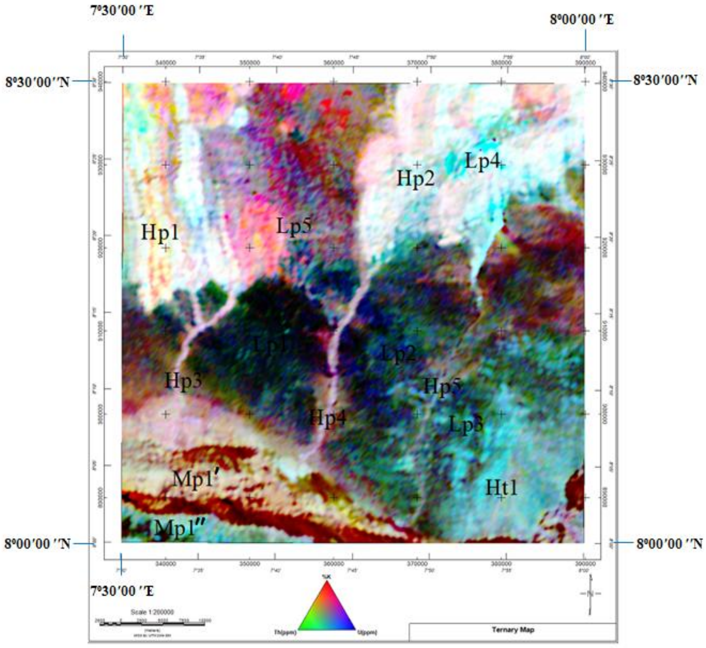

Figure 12. Ternary Images of %K, eTh, and eU within the study Area.

The formation associated with Mp1′ is dominated by potassium activities with occasional occurrences of high concentration of all the three radioelements and this is most likely due to the presence of sandstone, shale and carbonate of Lafia Formation. Mp1″ zone is highly dominated by thorium concentration, with occasional imprint of uranium and potassium activities and this is most likely due to the occurrences of shale and mudstone of the Nkporo Group.

Lp1, Lp2 and Lp3 have consistently recorded very low concentrations of potassium, uranium and thorium in all the three concentration maps of the radioactive elements and the ratio maps. Low concentration of all the three radioactive elements is characteristic of mafic to ultra-mafic volcanic rocks. It is therefore suggestive that the formations Lp1, Lp2 and Lp3 are mafic to ultramafic volcanic rocks. Mafic and ultra-mafic rock units are mostly located within the contact zones between volcanic rocks and their intervening sedimentary basins, and since Lp1, Lp2 and Lp3 are found between the meta-volcanic and their intervening metasediments, it is most likely that they are mafic to ultramafic volcanic formations. The ternary map (Figure 12) shows that these regions relatively have patches of high concentration of potassium compared to the other elements; however, they have consistently recorded low activities of all the radioactive elements. These suggest enrichment of potassium in the regions of Lp1, Lp2 and Lp3 compared to the other elements. The enrichment of potassium relative to the other elements, especially thorium is an indication of thermal alteration. This further suggests that Lp1 Lp2 and Lp3 regions have been altered thermally. Lp5 (Figure 12) is interpreted as migmatite (migmatite gneiss) rocks and it is characterised by potassic imprint and depleted radioactivity (dark zones). The dark (black) areas within the Lp1, Lp2 and Lp3 zones are places of lowest activities of all the three radioactive elements and which suggests that thermal alterations did not take place in these areas within the mafic volcanic units.

In the ternary map Ht1 zone recorded high concentration of thorium and uranium with the thorium content being slightly predominant. The zone also shows imprints of potassium concentration. The high concentration of thorium and uranium with imprints of potassium concentration in the zone suggests that the formation associated with the area is most likely granitic in nature (granite gneiss). Hp3, Hp4 and Hp5 zones have high concentration of thorium, potassium and uranium. Superposition of the radioelement maps with the topographic map of the study area revealed that the structures associated with them (Hp3, Hp4 and Hp5) are alluvia that accumulate at drainage valleys that trends NE-SW at the central part of the study area. Lp4 and Lp5 regions have high thorium and uranium concentrations; the zones are most likely thick alluvial cover that hosts minerals such as uraninite, thorite and uranothorite within the Udegi Complex.

Proposed Geological Map of the Study Area from Airborne Radiometric Data

The proposed geological map deduced from the airborne radiometric data over Udegi Complex and environs is presented in Figure 13. The interpreted rock units were named by relating the regional geology map of the study area to the interpreted geology from the airborne radiometric data. Six types of rock units were identified and delineated. These are the shale and mudstone unit of Nkporo Group, sandstone, shale and carbonates of Lafia Formation, the mafic volcanic units, granite gniess, the biotite granite of the Udegi Complex and the migmatite of the Central Basement Complex.

The delineated shale and mudstone units recorded high radiometric activities for all the three radioactive elements. The carbonate, shale and sandstone rich sediments recorded relatively high activity of potassium and moderate thorium and uranium concentrations. Notably, the high uranium and thorium concentrations observed in the study area are associated with the granite gnesis. The granite gneiss is well foliated, often magmatic and contains high content of thorium (Obaje 2009). The biotite granite associated with the Udegi Complex of North Central Nigeria is characterised by high concentration of all the three radioactive elements. During sodic metasomatism of the biotite granites a series of oxide ores, principally columbite and cassiterite, is disseminated throughout the apical zones.

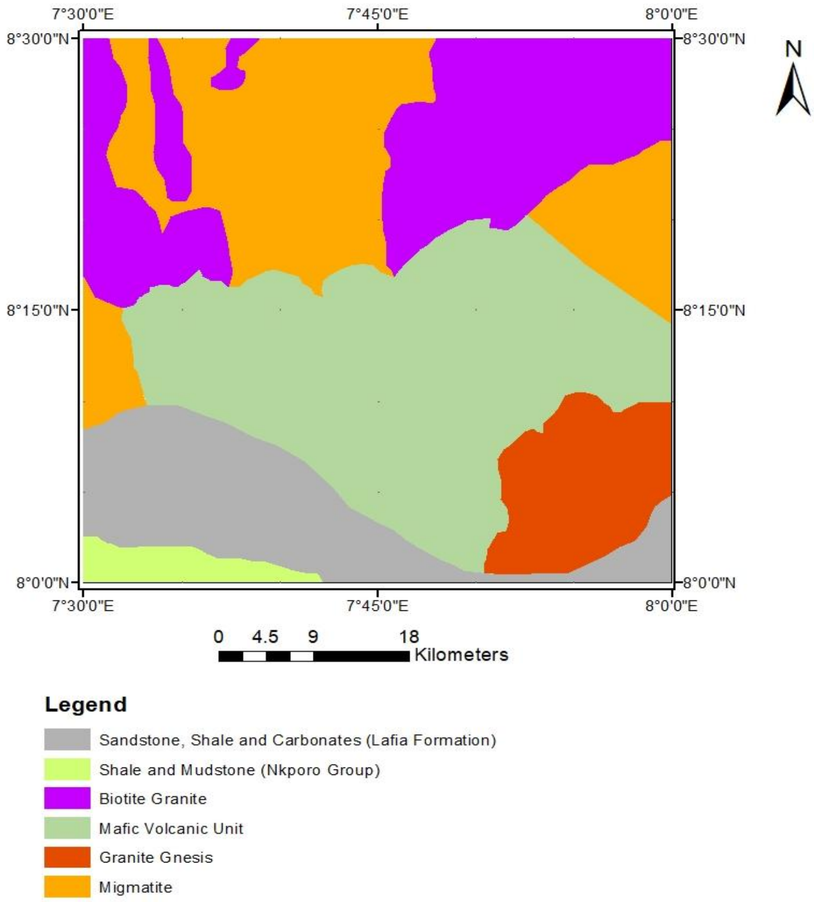

Figure 13. Interpreted Geological Map from Airborne Radiometric Data

Alteration within the Study Area

Rock alteration could be due to structural deformation, or chemical reaction (Wemegah et al. 2015) and mineralization in the Udegi Complex is associated with an event (thermal segregation of minerals) that resulted to rock alteration (Obaje 2009). The high concentration of all the three radioactive elements within the biotite granite rocks indicates that it has been thermally altered. The hydrothermal processes that affected the biotite granites is extensive and it resulted to the formation of disseminated and vein deposits of Sn, Zn, W and Nb with Cu, Fe, Bi, U and Rare Earth Elements (REE) developed in and around the roof and marginal zones of medium or fine-grained granite cupolas (Obaje 2009).

From the composite map (Figure 14), hydrothermally altered zones were delineated, especially in the mafic volcanic unit as well as within the sedimentary basin (Lafia and Nkporo formation). Sulphide mineralization is closely connected to thermally altered zones and is commonly controlled by both large scale and local structural and tectonic features within the Central Basement Complex of Nigeria. Evidence of alteration that preceded sulphide mineralization is best preserved in spatially associated altered mafic rocks (Mumin et al. 1996). The mafic and ultramafic units mapped, recorded an increase in K concentration due to intensive potassic alteration (biotitization and sericitization) which is a sulphide chemical alteration marker. Therefore, the areas that are thermally altered (Figure 14) are potential sites for sulphide mineralization.

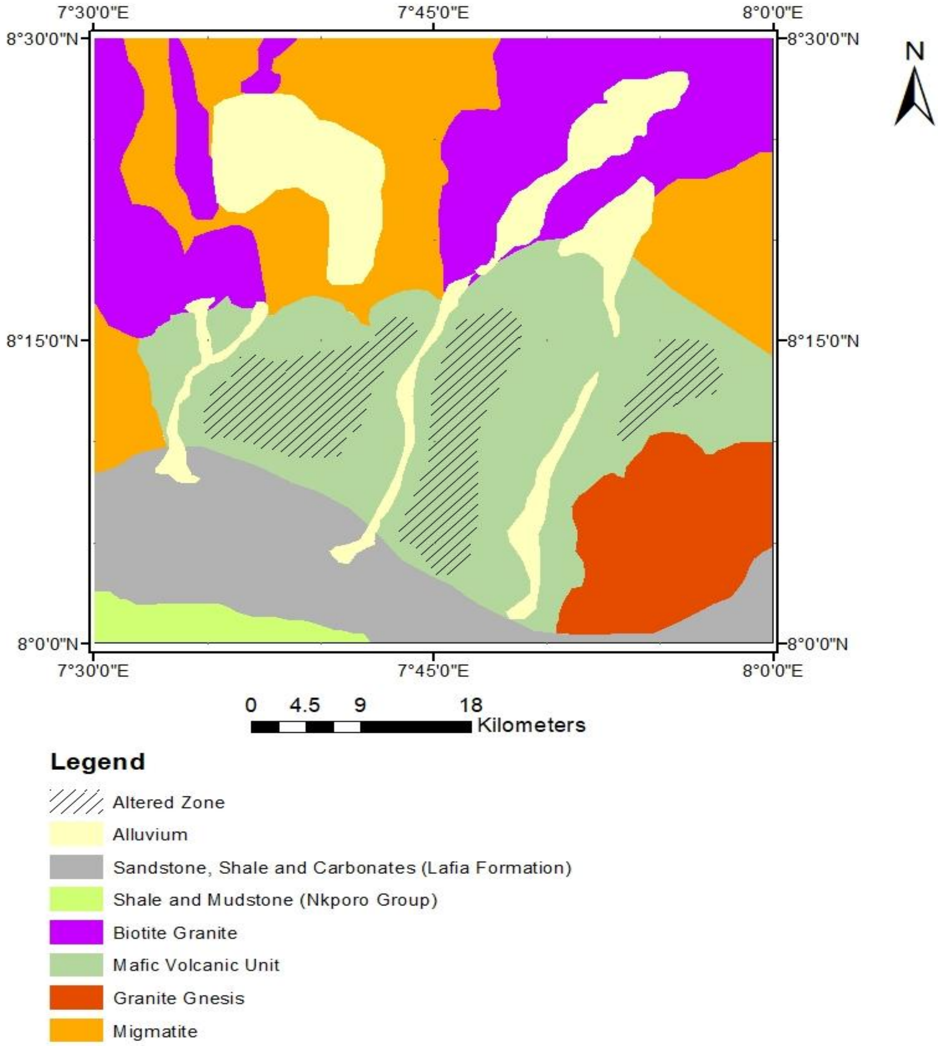

Figure 14. Composite Geological Map of the Study Area with Potential Zones of Cassiterite (Alluvium).

Potential Mineralized Zones within the Study Area

In determining the zones with cassiterite vein mineralization and alluvial – eluvial deposit within the study area, the alteration zones, topographic and geology maps were integrated. The altered Udegi Complex-biotite granite is characterised by disseminated and vein deposits of Sn, Zn, W and Nb with Cu, Fe, Bi, U and REE at and around the roof/apex and marginal zones of the formation. Unroofing by weathering/erosion of these ore-rich roofs yielded economically important alluvial and eluvial ore deposits at the lowland, especially the lowland at the center of the complex (Lp4 region). The alluvia within the Udegi Complex were delineated to host minerals such as thorite, uraninite and uranothorite and these are all associate minerals of cassiterite. Hence, the alluvia within the complex have great potentials of hosting cassiterite deposit in commercial quantity. Other zones with the potentials for accumulation of alluvial deposit are within the Hp3, Hp4 and Hp5 regions where they are formed from drainages of the Udegi Complex.

VI. Conclusion

This study delineated six geological rock units within Udegi Complex and environs, North Central Nigeria. They are shale and mudstone unit of Nkporo Group, sandstone, shale and carbonates of Lafia Formation, the mafic volcanic units, granite gniess, the biotite granite of the Udegi Complex and the migmatite of the Central Basement Complex. These NE-SW trending geological formations have intense structural deformations. Two major types of deposits occur within the area. The first is hydrothermal alteration reckoned with sulphide mineralization within the mafic to ultramafic metavolcanic rocks and the second is associated with disseminated and vein deposit of cassiterite and its associate minerals at the apex of the biotite granite rocks of the Udegi Complex. The unroofing of the apex by weathering/erosion yielded rich alluvial deposits within the alluviums of the study areas.

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