Geological Studies on Uranium, Thorium, Potassium Based On Airborne Radiometric Geophysical Data of Wukari And Donga Middle Benue Trough Nigeria

Nwobodo, A.N1,.Ikeri, H.I2,.Chikeleze, P C3.
1,2 Department Of Industrial Physics ,Enugu State University Of Science And Technology
3 Department Of Physics And Astronomy, University Of Nigeria, Nsukka

ABSTRACT
The high resolution aeroradiometric data of Wukari and Donga Middle Benue Trough used for this work were obtained from the Nigeria Geological Survey Agency (NGSA). The analysis of radiometric data revealed concentrations distribution pattern of primary radioelements: potassium (K), thorium (Th) and uranium (U). The count rate range of K (0.11 - 2.75%), Th (6.79 - 27.71 ppm) and U (1.69 - 6.21 ppm) were observed within the study area. From the analysis of the maps, the relative lower values of Uranium abundances in Wukari area are roughly related to the presence of sedimentary rocks such as carbonates and sandstones in the study area while higher values of Uranium abundances in Donga area are roughly related to the presence of metamorphic rock such as schist. Results from statistics and map analysis have shown that the concentration of potassium is dominant around southern and northwestern part of Donga and Wukari area respectively and is of great advantage to agriculture in the area. In order to map out the most probable areas of radiometric mineralization, threshold values of U, Th and K% concentrations were determined statistically. The threshold value (the highest activity) for the total count was estimated as 51 cps. The approximate areas with sources of radiation which produce this anomaly (> 51 cps) are dominant in southern part of Donga area. Therefore, only the anomaly in these areas may be significant in terms of radioactive mineralization. The identified area should therefore be considered for further detailed ground spectrometric survey so as to determine the radiometric mineralization potentials of the area.

KEYWORDS: radiometric, mineralization, spectrometric survey, threshold value

I. INTRODUCTION
Airborne Radiometric survey has recently attracted great interests both for economic and environmental reasons. The technique originally targeted for Uranium exploration is now widely used for geologic mapping (Andrson and Nash,1997), mineral exploration and environmental radiation monitoring and control (Hashad,1982). Mapping the surface geology by radiometric survey is based on the fundamental assumption that different rocks are compose of rock- forming minerals which contain specific amount of radioactive elements. Radiometric method produces exceptional radioactive results in the mapping of the various kinds of geological formations (Kearey et al., 2002; Milsom, 2003). According to Telford et al. 1990, there are at least 20 known naturally occurring radioactive elements of which only three elements namely, Uranium U, Thorium Th, and Potassium K have isotopes that produce gamma radiation of high energy and intensity to be measured by spectrometry. Among the gamma rays U and Th are of significant interest as sources of fuel for generation of power and heat in nuclear plants (Telford et al., 1990). Variations in U, Th and K respectively contributes to changes in the geologic lithology; therefore airborne radiometric survey can be used as a reconnaissance mapping tool. In Nigeria information on uranium occurrences have been identified by few individuals who have analyzed a few rock samples and uranium ores from some locations around the Nigerian younger granite province. However, the works of Uwah (1984), Dewu (1986), and Ahmed (2006) who carried out detailed investigations of radiometric anomalies in the Sokoto Basin, Bischie and Jingir areas of Sokoto and Plateau States respectively, form a very important step for a large scale exploration of uranium and allied minerals. Arabi et al. (2012) investigated the levels of concentration of uranium in groundwater to ascertain its compliance with the World Health Organization’s and United State Environmental Protection Agency’s guidelines for uranium in drinking water in the northeastern part of Nigeria. Recently researchers like (Ayodeji et al. (2011); Abdullahi (2013); Taiwo et al. (2014) and Arabi et al. (2012; 2015)) carried out research in radiometrics in the northern and northeastern part of Nigeria. In this research airborne data were presented and interpreted to map different lithologic units of the area based on the spatial differences in the U, Th and K contents. The aim of this study is to carry out statistical analysis on the data in order to obtain the threshold
value and the expected mean activity of the radioelements present in the study area and this will help to delineate the most favourable areas of radiometric anomalies and also areas rich for agriculture.

II. LOCATION AND GEOLOGY OF THE STUDY AREA

The study areas with the geographical coordinates of latitude 9.5° to 10.5° North and longitude 7.5° to 8.0° East with an area extent of approximately 6050 km² are located in the middle Benue trough, Nigeria. The middle Benue trough links the upper and lower arms of the Benue trough sedimentary basin in Nigeria. It is part of a long stretch arm of the Central African rift system and one of about seven inland sedimentary basins in Nigeria (Fig. 1) originating from the early Cretaceous rifling of the central West African basement uplift. The Benue trough is a unique rift feature on the African continent. It occupies an intracontinental position and has a thick compressionally folded Cretaceous supercrustal fill, and divisible into upper, middle and lower Benue (Samuel et al., 2011). The area is characterized by the presence of thick sedimentary cover of varied composition whose age ranges from Albian to Maastrichtian (Obaje, 2004). Fig. 2 is the Stratigraphic succession of the Benue trough (Obaje et al., 2004). The Cretaceous sedimentary succession in the middle Benue trough (beginning from the oldest to the youngest) consists of the Asu River Group, the Awe, Keana, Eze-Aku, Awgu and Lafia Formations. The marine Asu-River group of Abian age commenced the sedimentation in the Middle Benue trough (Obaje, 2004; Obaje et al., 2004).

Fig. 1: Geological map of the study area (Obaje, 2004)
III. SOURCE OF DATA
The high resolution airborne radiometric data of Wukari (sheet 253) and Donga (sheet 254) used for this study were acquired from Nigerian Geological Survey Agency, Abuja (NGSA). The high resolution airborne survey were carried out by Fugro Airborne Survey between the years 2002 - 2009. The data obtained from the airborne survey was presented in digital form as a composite grid of 1:100,000 sheets covering the study area. The data were acquired at a flight elevation of 80 m, line spacing and tie-line spacing were 500 m and 5000 m respectively.

IV. METHOD OF DATA ANALYSIS
Gridding of the aeromagnetic data was one of the first steps adopted in the data analysis because imaging, processing and interpretation require the data to be converted to an evenly spaced two dimension (2D) grid. The data was gridded in order to produce the Total count, uranium, thorium and potassium maps (Figs. 4-7) of the study area using Oasis Montaj software (www.geosoft.com).

The statistical analysis on the airborne radiometric data were carried out using the geostatistical tool of Oasis montaj 8.4 software (Figs. 3(a-d)). The statistical parameters such as the mean, standard deviation (SD), standard error of mean(SEM), skewness, kurtosis, geometric mean (GM), mode, minimum and maximum values, median, threshold value and expected mean activity (EMA) for the measured gamma radiation were calculated. The normal or expected mean activity (EMA) is determined from the mode and standard deviation (SD). The SD gives an idea of how close the entire set of data is to the mean value (Mammoth Geophysical Inc., 2007). According to Duval (1979), the SD is given as:

\[ \text{EMA} = \text{Mode} \pm \text{SD} \]

The threshold values of \( eU \), \( eTh \) and \( K\% \) concentrations were determined statistically as described in equation 2 in order to map out the most probable areas of radiometric mineralization. Statistically, the threshold value is the sum of the mean and standard deviation and any value above the threshold is considered anomalous (Mammoth Geophysical Inc., 2007; Yusuf, 2016):

\[ \text{Threshold value} = \text{mean} + \text{Standard deviation} \]

Fig. 2: Stratigraphic succession in the Benue trough (Obaje et al., 2004)
Fig. 3a: Statistical analysis of potassium

Fig. 3b: Statistical analysis of Thorium

Fig. 3c: Statistical analysis of Uranium
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Fig. 3d: Statistical analysis of the Total count

Fig. 4: Total Airborne Radiometric Anomalies count map of the study area.
Fig. 5: Geographic distribution of Uranium in the study area.

Fig. 6: Geographic distribution of Thorium in the study area.
V. RESULTS AND DISCUSSION OF RESULTS

The analysis of radiometric datasets revealed concentrations distribution pattern of primary radioelements: potassium (K), thorium (Th) and uranium (U). The result obtained was used to delineate and characterize bedrock lithology, as well as alteration and rock contacts within the study area. The count rate range of K (0.2 to 3.8 %), Th (7.0 - 59.5 ppm) and U (2.0 - 9.5 ppm) were observed within the study area. Fig. 4 is the total count of the three radio-elements (Uranium (ppm), Thorium (ppm) and Potassium (%)) with a total count of about 1034.3cpt – 6291.0 cpt map of the study area. The map shows high concentration of total count values in parts of the study area mostly around Donga. From the threshold values (Table 1), the maps of Uranium, Thorium and Potassium concentrations (Fig. 5-7) respectively have delineated areas of more prominent radioactive anomalies of the radioelements. The Thorium above threshold map (Fig. 6) shows the concentration of thorium in the Donga part of the study area. Potassium is concentrated in southern and northwestern part of Donga and Wukari area respectively of the study area (Fig. 7).

The threshold value (the highest activity) for the total count was estimated as 51 cps which according to Uwah (1984), all other values higher than the threshold value are considered anomalous. In Fig. 4, the approximate areas with sources of radiation which produce this anomaly (> 51 cps) are dominant in southern part of Donga area. Therefore, only the anomaly in these areas as indicated with pink colour may be significant in terms of radionuclide mineralization. Also, According to Levinson (1974), for an activity to be of significance in terms of mineralization, it must be about twice the mean activity of the area. In the study area, activities of more than twice the mean activity (i.e. 28 cps) was dominantly observed at Donga part of the study area as shown in Fig. 4 with pink colour.

The standard deviation were determined statistically as shown in Table 1. The standard deviation of the concentrations of the radionuclides U in this study are lesser than its mean activity concentrations which
indicates a high degree of uniformity while Th and K are greater than their mean activity concentrations which indicates a low degree of uniformity (Gupta, 2001). The mean concentration of U, Th and K for the data, are 3.73 ppm, 14.83 ppm and 1.137% respectively which are within the world average values (UNSCEAR, 2000).

VI. CONCLUSION

The radiometric data of Wukari and Donga has been interpreted quantitatively and qualitatively. The result from the analysis of the radiometric data revealed the concentrations of the radioelements, potassium (K), thorium (Th) and uranium (U) in the study area. The result obtained was used to delineate and characterize bedrock lithology, as well as alteration and rock contacts within the study area. The count rate range of K (0.2 to 3.8%), Th (7.0 - 59.5 ppm) and U (2.0 - 9.5 ppm) were observed within the study area. Results from statistics and map analysis have shown that the concentration of potassium is dominant around southern and northwestern part of Donga and Wukari area respectively and is of great advantage to agriculture in the area. The mean concentration of U, Th and K for the data, are 3.73 ppm, 14.83 ppm and 1.137% respectively which are within the world average values. In order to map out the most probable areas of radiometric mineralization, threshold values of eU, eTh and K% concentrations were determined statistically. The threshold value (the highest activity) for the total count was estimated as 51 cps. The approximate areas with sources of radiation which produce this anomaly (> 51 cps) are dominant in southern part of Donga area. Therefore, only the anomaly in these areas may be significant in terms of radioelement mineralization.

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REFERENCE


