Preliminary Investigation of Some Radiometric Anomalies at Kufena Ring Complex, Zaria Kaduna State, Using Gamma Ray Scintillometer.

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ABSTRACT

The Kufena Ring Complex, Northern Nigeria, was preliminary surveyed with a view to selecting an area for detailed ground investigation to determine the radioelement potentials of the region. The survey revealed some anomalies in the rock types, out of which the albite-riebeckite rocks of the area were delineated as significant in terms of radioactive mineralization. This area (the albite-riebeckite granites) where high counts were recorded was chosen for further ground investigation. Analyses of the data revealed uranium and thorium enrichments in the albite granites between latitudes 10^{o}50'N and longitudes 10^{o}51' and longitude 8^{o}14' and 8^{o}15'E. About 20% of the surveyed area could be characterized as an area of possible uranium mineralization. The study also revealed that atmospheric and cosmic ray backgrounds have very little effect on the total background activities measured in the survey area.

(Keywords: radioelement, radioecology, mineralization, uranium deposits, geological surveys)

INTRODUCTION

As far back as 1921, the Nigerian Geological Survey has discovered some unusual granite having quartz, albite, perthite, and riebeckite as essential minerals and cryolite and pyrochlore as somewhat common accessories (Mackay and Beer, 1952).

Geological and Geophysical surveys in search of uranium deposits could be said to have started in Nigeria in 1947 when the mineral pyrochlore, containing substantial amount of uranium was discovered by the Geological Survey Department in small granite bodies on the Jos-plateau. In 1949, Mackay who was in Nigeria on a thorium investigation considered that it would be worth while to examine some of these granitic bodies in order to see whether the pyrochlore was present in sufficient amount to provide a likely source of uranium or thorium. Of the four albite-riebeckite granitic masses studied, that at kaffo is the most interesting from an economic standpoint. It has proved radioactive within an area of 195 acres averaging 0.012% U_3O_8 determined chemically. This figure does not agree with the radiometric average, which is 0.028% equivalent U_3O_8 but which also includes other radioactive elements (Mackay and Beer, 1952).

In 1969, an airborne radiometric survey covering 85,000km^2 was undertaken by the International Resources Cooperation for ocean exploration of the United States. The survey covered two areas underlain by sediments of the Gundumi Illo formation, Bima and Yolde formations in the then Sokoto, Bauchi, and Borno divisions, respectively. Though some areas with radiometric anomalies were identified, no ground follow up was carried out (OECD and IAEA, 1979).

In 1973/74, the Geological survey department contracted out the airborne gamma spectrometer surveying of four contigious areas;

1. Sokoto and Middle Niger areas
2. Central North (katsina-Jos)
3. Lower Benue and Adjoining areas
4. Upper Benue and Adjoining regions

These surveys were completed and reports submitted in 1975/76. The Geological Survey Department commenced group follow-up in 1976. This program consisted of traversing identified areas with gamma spectrometers and scintillometers followed by detailed radiometric survey on grids, geological mapping, pitting, trenching, and diamond drilling. Areas covered include about 20,000 Km^2 in Sokoto State, 10,000 Km^2 in Cross River and Benue States, and 8,000km^2 in the Niger and Benue Rivers confluence area of Northern Nigeria. No appreciable quantity of uranium was found; therefore no further drilling was carried out (OECD & IAEA, 1979).

In 1975, the Nigeria Mining Corporation carried out a feasibility study on the prospect or uranium mineralization in Nigeria. This was followed by a geochemical and reconnaissance ground traversing with scintillomters. A total are 35,000km^2 in North-Eastern Nigeria was covered in this program. This program was expanded in 1981 to include the central area of Nigeria. Reconnaissance field work commenced in October, 1981.

Readings were taken using total count scintillometers (SSP2) and the results were contoured on a map of 1:100,000 standard sheets (Dada et al., 1982). In a report in 1979, the (OECD) expected an increase in the success of the efforts then. It however noted that the Federal Government position on U exploration was not clear although decrees establishing the Nigeria Atomic Energy Commission (NAEC) and Energy Commission of Nigeria (ECN) were promulgated. The need for such commissions necessarily means an increase in the area of Uranium exploration or in the exploration of the radioelements to the industry and Government establishment. Also, the need for nuclear energy to play a prominent role in future energy supply was clearly demonstrated in the concluding report of the world energy conference (WEC) released in September 1978. All these mean that there is going to be an increase in the area of Uranium exploration both locally and internationally.

In Nigeria. Already, the initial stage in the large scale exploration for the radio-element was launched when high sensitivity aero-radiometric surveys were carried out in 1975. the survey covered the lower Benue area, the middle Niger and the Sokoto are conducted by Fairly Surveys Ltd. and Hunting Geology and Geophysics Ltd., respectively, on behalf of the Federal Ministry of Mines and Power.

Although intensive ground follow-up surveys have been carried out in some area since 1977 (for example the Nigeria Uranium Mining Company (NUMCO), the Nigerian Mining Corporation, the Geological Survey of Nigeria and by the University of Ife), there is very little information on Uranium occurrences in Nigeria. The little available information on uranium occurrences in Nigeria are mainly from individuals who have analyzed a few rock samples and uranium ores from some locations around the Nigerian younger granite province. However, the work of Uwah (1984), Dewu (1986), and Ahmed (1994) who carried out detailed investigation of radiometric anomalies in the Sokoto Basin, Bisichi and Jingir areas of Sokoto, and the plateau states respectively, form, a very important step for a large scale exploration of uranium and allied minerals.

The main requirement of the future of nuclear power is the development of hidden ore bodies. A fuel supply is intrinsically fundamental to the sustainability of any energy system. Therefore it is essential that all stake holders with an interest in understanding nuclear fuel supply have available a systematic analysis of the long term uranium supply (STI/PUB/, 2001).

At Kufena complex where the present work is based, spectrometric survey was carried out by Hunting Geology and Geophysics Ltd. in 1974 and a contour map was produced in 1975. The map revealed an anomaly with high uranium and thorium amplitudes within the complex. Abaa, in 1976, confirmed using geochemical methods that there is uranium and thorium enrichment at Kufena complex, though the mineralization is a dispersed one. There is thus the need for detailed ground radiometric surveys to characterize the uranium and thorium contents in the area.The present work can therefore be considered as the first detailed ground radiometric investigations to delineate favorable uranium targets within the complex. Method of investigation is in-situ scintillometer survey.

GEOLOGY OF KUFENA

The Kufena intrusion is a small granite massif near Kufena village in the north-west corner of the Nigeria Younger Granite province and occupies an area of 6.34 km^2. It is situated about 64km NSE of Zaria City and located at $8^0$13'E and $10^0$49'N to $10^0$52'N on sheet 125 NW of Northern Nigeria survey ordinance map 1966. The intrusion rises to about 120m above the surrounding Basement rocks and plains. The intrusion is one of the most westerly of the Jurassic younger granites (Figure1) that occur in a 200km wide North-south zone in central Nigeria, concentrating more around the Jos Plateau (Bowden et al., 1976).

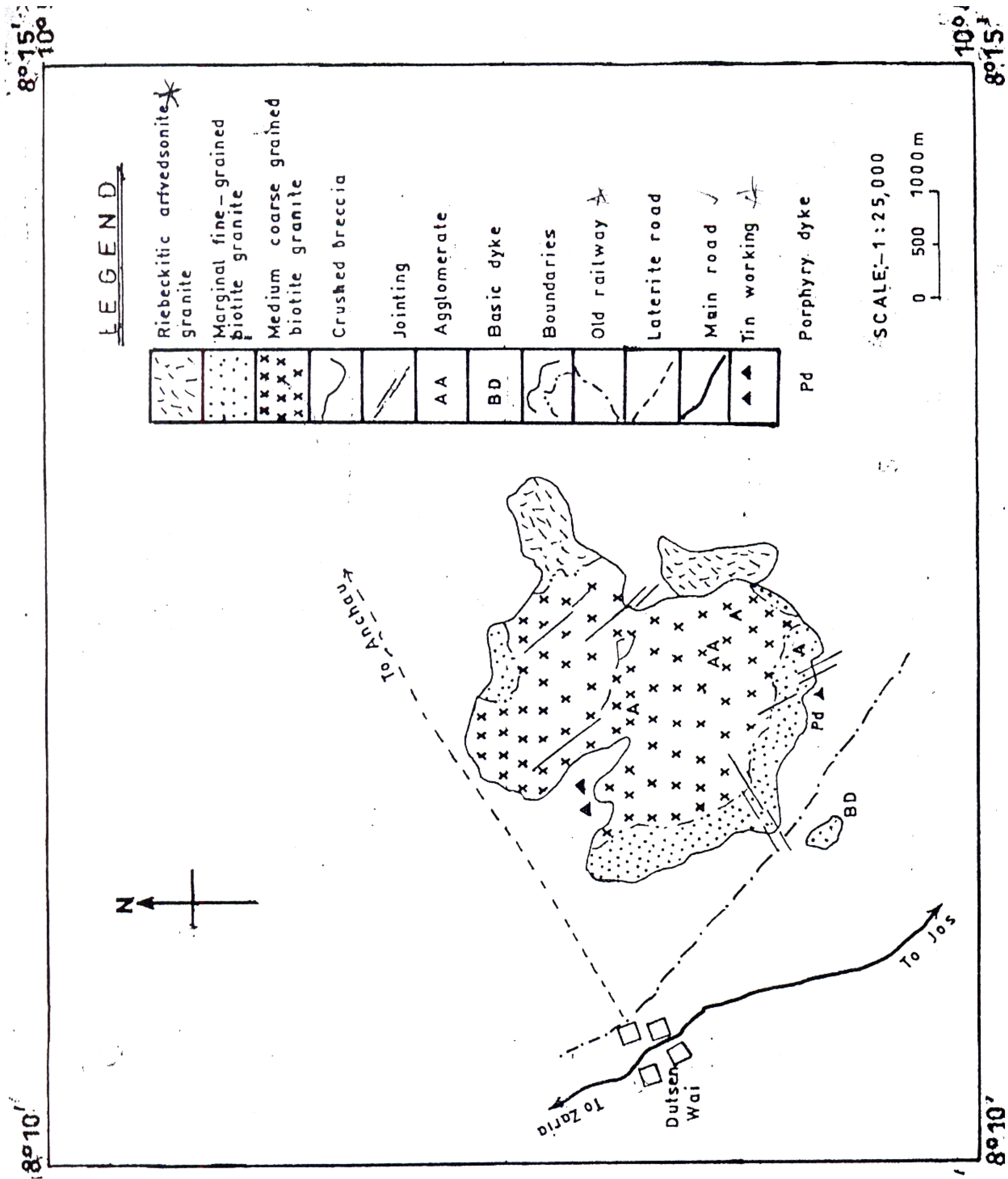

Figure 1: Geological Map of Kufena (After Jacobson and Maclead, 1977).

The Kufena complex exhibits a simple granite intrusion on the eastern side of the structure. The inner contact with the basement and the biotite is characterized by extensive pegmitization and silicification such that its attitude of the contact cannot be determined. The outer boundary is masked in the low swampy ground to the east and south and the degree of exposure becomes progressively less on moving away from the inner contact.

The flat land surrounding the intrusion is composed mainly of gneisses, migmatites and recent alluvials. The massif has sharp contacts with the basement rocks which are low lying outcrops. The Basement rocks however rise steeply at the contacts with the intrusion in the south-west and southern parts of the intrusion, reaching about 50 high in some places. The Younger Granites have gentle dips towards and under the Basement rocks; Ajakaiye and Sweeney (1974) described the Kufena intrusion as a high level, thin, tabular body with subsurface extension of felsic material, dominantly biotite granite, well beyond the outcrop limits of the complex in all directions. Further away from the intrusion, the migmatites and gneisses give way to predominantly recent alluvials extending far and wide in all directions uninterrupted.

OBJECTIVES OF THE PRESENT STUDY

The objectives of the present study are:

1. To carry out the area for possible indication of radioactive mineralization
2. To identify area of high radioactivity that are possibly indicative of radioactive mineralization for further spectrometric study.

FIELD TECHNIQUES AND INSTRUMENTATION

The site was surveyed using the scintillometer. The rocks of the area were classified into three categories according to their sites of occurrence namely:

Site 1: fine grained biotite granites
Site 2: Medium to coarse grained biotite granites
Site 3: The riebeckite airfvedsonite granites.

The scintillometer used was the Exploranium® portable gamma ray scintillometer, model GR-101A manufactured by Geometrics Inc California. The GR-101A scintillometer is an instrument that transforms incident gamma radiation into a visual red out of radioactive intensity as a function of the natural radioactive material present in the geologic formation. A sodium iodide crystal converts gamma rays into faint flashes of light whose brilliance is proportional to the energy level of the gamma radiation measured.

These light flashes are detected by a high gain photomultipier tube (PMT) amplified, and fed to a circuit which accepts only these signals above a certain energy. The accepted signals are average in a ratemeter circuit as counts per second and continuously displayed on a 250^0 meter on the instrument front panel. The frequency or signal count rate displayed is the intensity of all gamma ray energy above the present threshold.

The detector crystal was a sodium iodine thallium activated NaI cylinder of dimensions 38.1mm x 38.1mm, giving a total crystal volume of $0.0431m^3$. The instrument recorded gross count only for all gamma rays of energies above 0.05 meV (Mcdermott, 1977). It also provided visual and audile indications of anomalous gamma radiation from local sources of radioactivity. Readings were taken at random points with the instrument along with Global positioning system (GPS), which was used to measure the coordinates (Latitude and longitude) at each random point.

With the scintillometer strapped at waist height above the ground as recommended by the manufacturers, the average background count of the area was then deduced from the scintillometer readings at several locations covering a large portion of the area. The scintillometer was then set to sound the audio alarm whenever its reading exceeded about twice the average background count for the area.

To estimate the cosmic ray contribution to the ground activity measured in the field, readings were also taken at River Koggi in Zaria before starting the survey and the day the survey was completed. The readings were very low and therefore neglected. The average background was also very low at all the 3 sites.

With the instrument again in its shoulder pouch and carried at waist height above the ground, all the three sites were traversed on foot and readings were taken at random points. The coordinates of these points (Latitude and longitude) were also recorded using the GPS> it was observed that high counts were recorded at site 3 (the Riebeckite Granites).

This area was mapped out and anomalous areas were selected for detailed spectrometric survey. The gross counts for sites 1 and 2 were also mapped out. Readings were not taken between 6.00am to 10:00am when the harmattan blew wind fiercely across the area because background readings were usually high then.

DATA REDUCTION

The data were corrected for background and were contoured using the surfer program. The uncertainties attached to the count rates are the 90% confidence limits of the mean activities. Contour maps of the count rates for sites 1, 2 and 3 and shown in Figures 2, 3, and 4, respectively. The counts were generally higher at site 3. One prominent peaks centered at (10.8333^0, 8.2400^0) at site 3 and two prominent peaks centred at (10.8470^0, 8.2500^0) and (10.8440^0, 8.2180^0) were observed. No such defined anomalies were observed fort site 2 (Figure 3). The anomaly at site 3 is broader and more pronounced. The observation in the field was that areas of high activities coincided with areas with reibeckite granites while areas depicting the lowest activities correlate with biotite granites areas. These anomalies observed may be significant in terms of radioactive mineralization.

DATA ANALYSIS

Geologic formations are not necessarily uniform in radioactivity. Therefore calculations of average values of field activities and of standard deviations can be in error if an attempt is not made to unify them.

The gross count contour maps can be used to delineate areas of radioactive mineralization. According to Uwah, 1984, a better method of determining the average value of acclivity for a geologic unit is to plot a frequency distribution of the number of data points with a given activity versus the activity. Figs 3.4 and 3.5 show such frequency distribution curves for site 1 and 3. The mean activity is the mode of the frequency distribution. The normal or the expected value of activity for each site was obtained from the two frequency curves as follows:

For site 1: the mode = 7 cps (Figure 5)

The full width at half maximum (FWHM) =

$$\frac{2.6 + 1.6 + 1.6 + 1.4}{4}$$

FWHM = 1.8

The standard deviation (SD) is then given by Duval, (1979) as:

SD = FWHM x 0.75

Therefore SD = 1.8 x 0.75

SD = 1

The normal or the expected mean value of activity LB for site 1 is then given by:

LB = Mode + Sd
= (7+1) cps

The threshold value for site 1 (the highest activity) is therefore 8 cps all other values higher than 8 cps are considered anomalous. In Figure 2, the approximate areas of sources of radiation which produce this anomaly are bounded by the 8 cps contour line. Therefore only the anomaly centered at (10.8440^0, 8.2180^0) may be significant in terms of radioactive mineralization.

For site 3: the mode = cps (Figure 6)

$$\text{The FWHM} = \frac{2 + 2 + 2 + 6 + 14.5 + 5 + 8.5}{7}$$

FWHM = 5.7

Standard deviation SD
SD = FWHM x 0.75

SD = 4

LB for site 3 = (9 + 4) cps

The threshold value for site 3 is therefore 13 cps. All other values higher than the threshold are considered anomalous. In Figure 4, the anomalous areas were considered as those areas bounded by the 17 cps contour line.

CONCLUSION

According to Levinson (1974), for an activity to be of significance in terms of mineralization, it must be about twice the mean activity for the area.

At site 1, activities of 14 cps and above, which was more than twice the mode of 7 cps for the area (Figure 5) was measured only at point. No defined anomalies were detected at site 2. At site 3, activities of 18 cps and above that are twice the average mode for the entire area were measured at 33 points (Figure 6). This means that the anomaly delineated at site 3, which has high radioactive count is more significant.

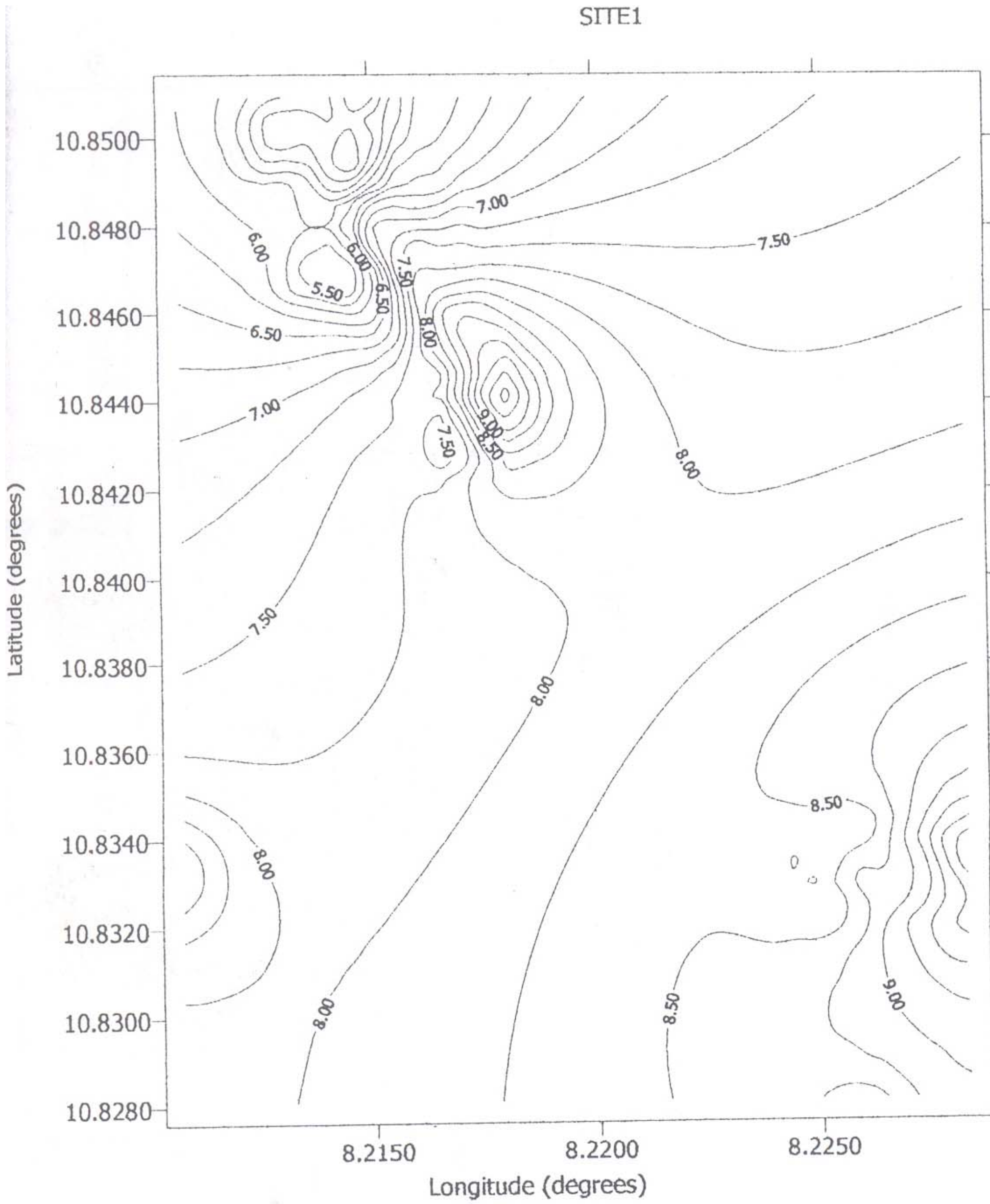

Figure 2: Contour Map of Count Rates for Site 1. Contour Interval is 0.25 cps.

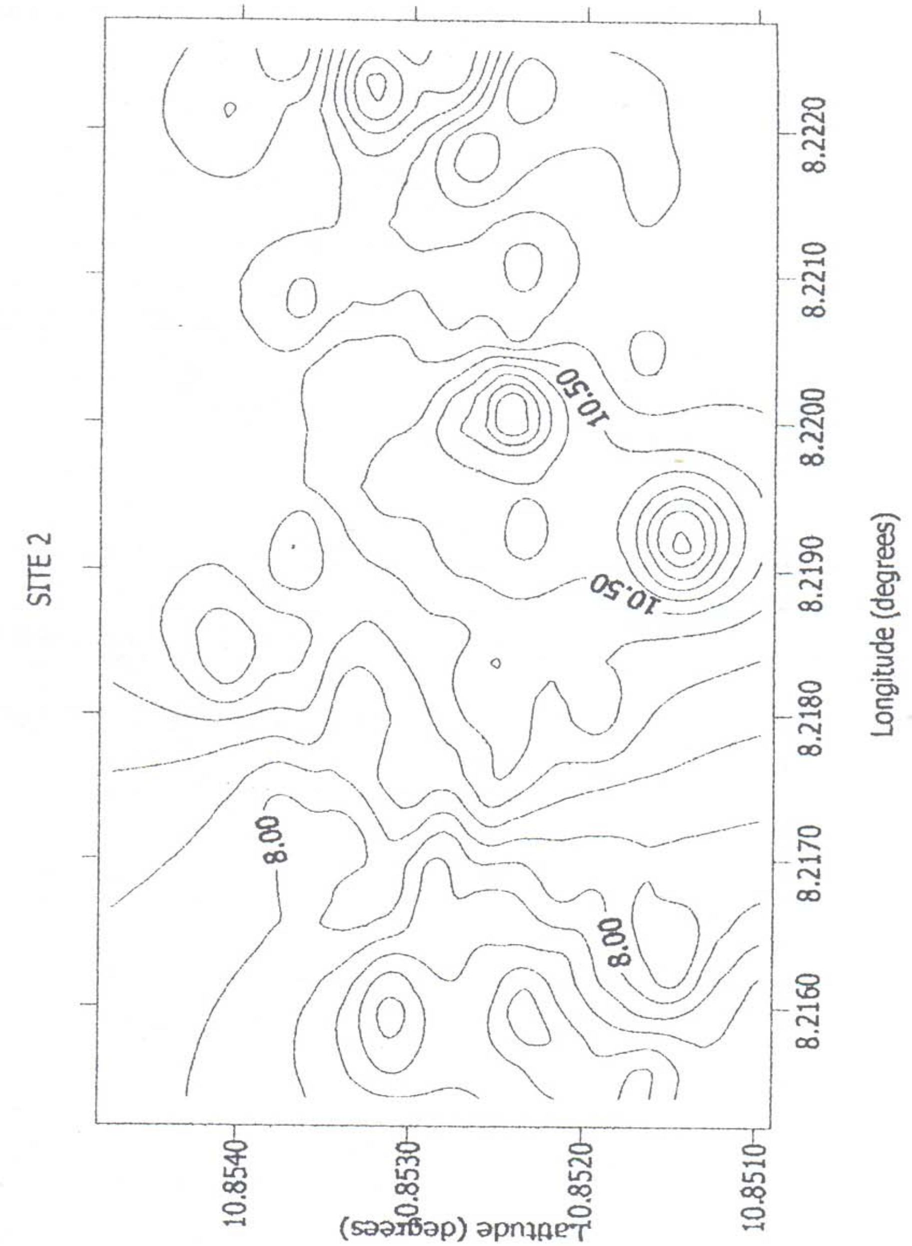

Figure 3: Contour Map of Count Rates for Site 2. Contour Interval is 0.5 cps.

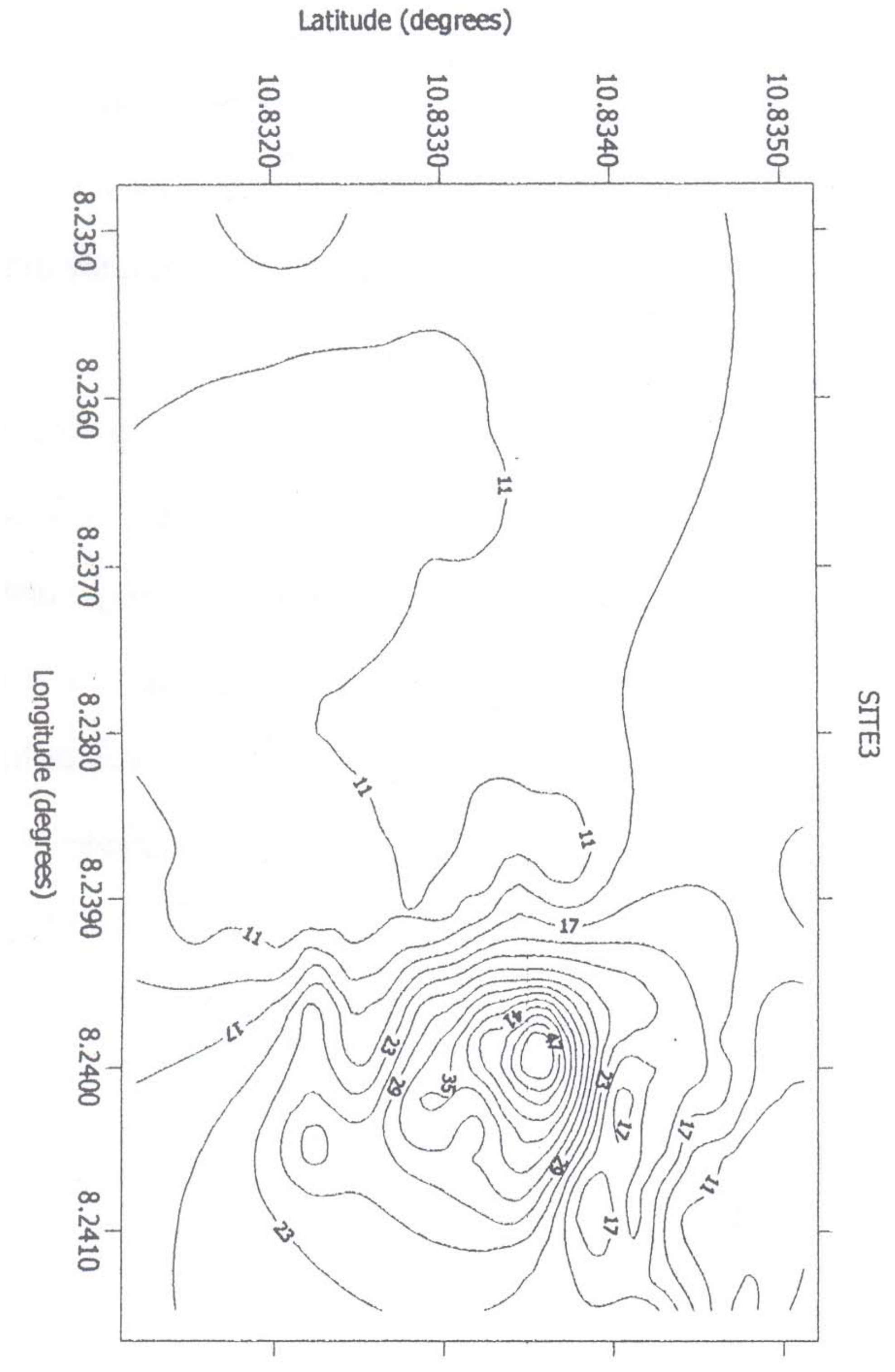

Figure 4: Contour Map of Count Rates for Site 2. Contour Interval is 3.0 cps.

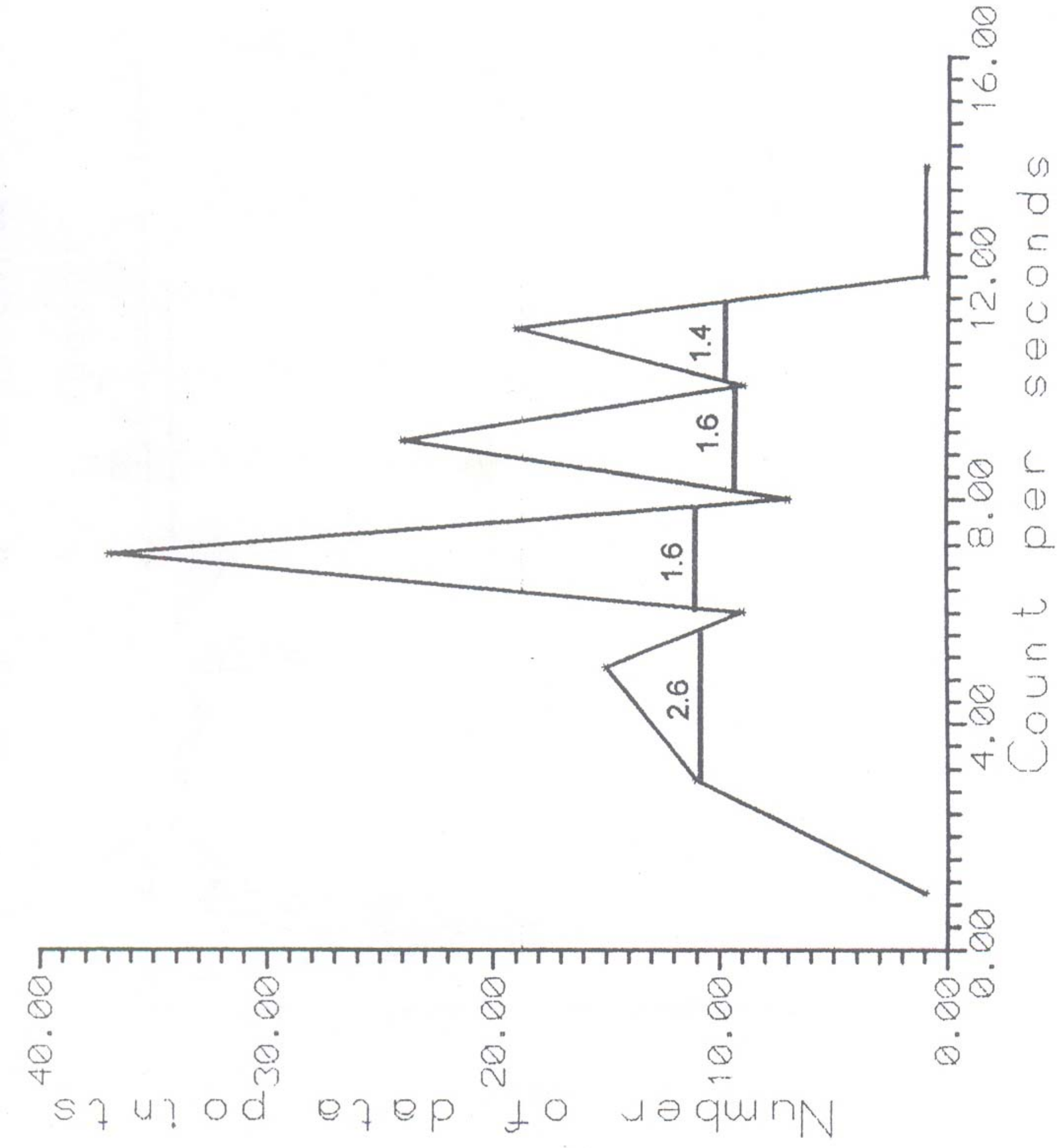

Figure 5: Frequency Distribution of Count Rates for Site 1.

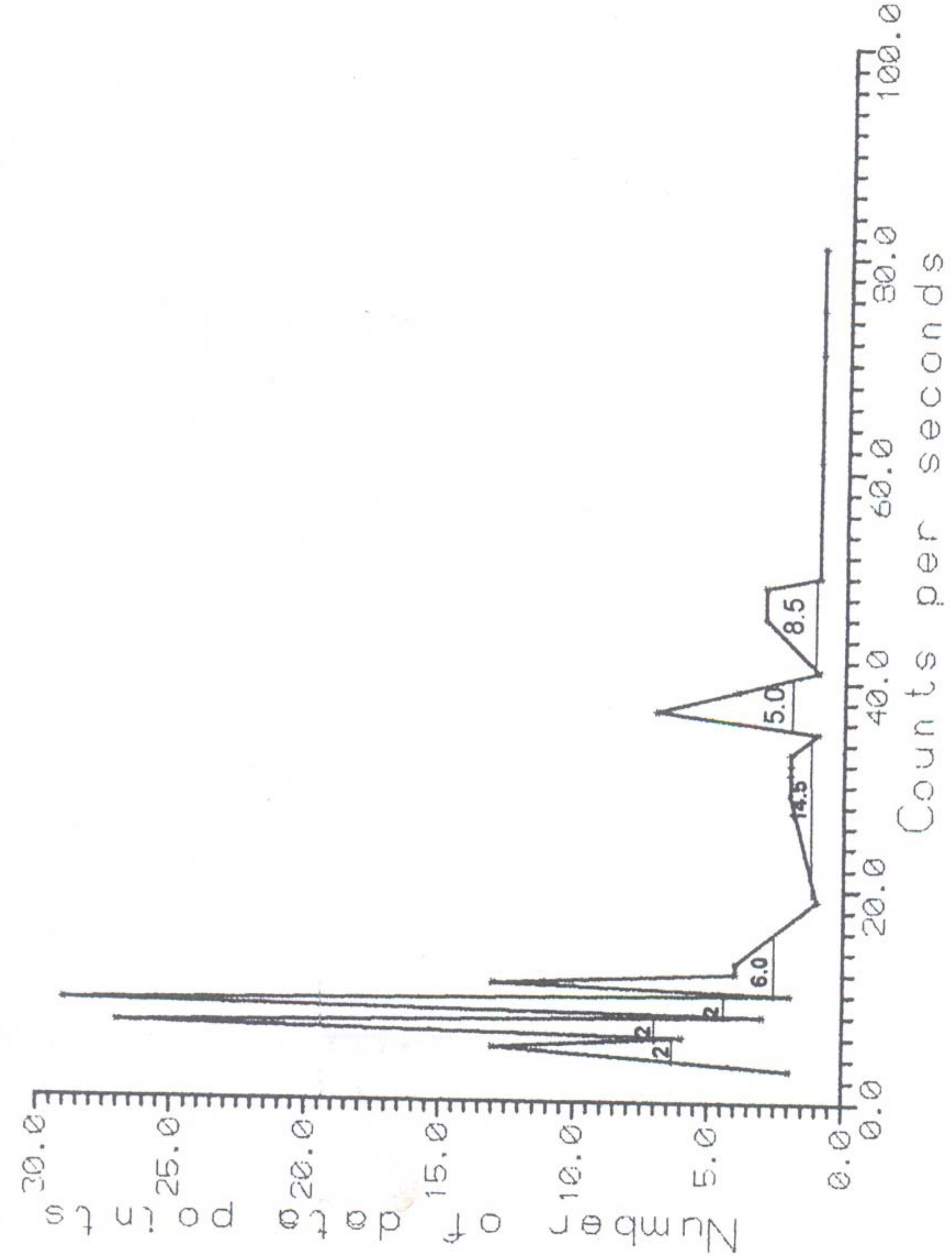

Figure 6: Frequency Distribution of Count Rates for Site 3.

Therefore, site 3 (the albite-riebeckite area), which is at the north eastern part of the complex, 6 km away from samaru is more promising in terms of radioactive mineralization and was the site considered for detailed gamma ray spectrometric survey.

RECOMMENDATIONS

Because of the sources of errors (poor sensitivity due to small crystal volume, excessive channel fluctuations and the inability to measure accurately the cosmic ray background) associated with the instrument however, it is recommended that more work should be done to assess the extent of U mineralization of the albite-riebeckite-arfvedsonite granite with pyrochlore. A more sensitive "window type spectrometer" with large crystal volume which was not available at the time of this study will be more suitable for in-situ measurements in this survey area. Also, instrument calibration facilities should be sought for, so as to check the calibration constant supplied by the manufacturers for the determinations of uranium, thorium and potassium concentrations.

REFERENCES

1. Ahmed, A.L. 1994. "Ground Follow-up Surveys of some Radiometric Anomalies at Jingir, Plateau State, Using Gamma Ray Spectrometry". Unpublished M.Sc Thesis, Ahmadu Bello University, Zaria. Pp 1-90

2. Ajakaiye, D.E. and Sweeney, J.F. 1974. "Three Dimensional Gravity Interpretation of the Dutsen-wai Complex Nigerian Younger Granite Province". *Tectonophysics*. 24: 331-341.

3. Bowden, P., Van Breeman, O., Hutchinson, J., and Turner, D. C. (1976). Paleozoic and Mesozoic Age Trends for Some Ring Complexes in Niger and Nigeria". *Nature*. 259(5541):297-299.

4. Dada, S.S., Dandume, S.G., and Binyoti, F. 1982. *Central Nigeria Mineral Exploration Project*. Nigerian Mining Corporation Report. Pp 6-23.

5. Dewu, B.B.M. 1989. "Distribution of Uranium in Granite and Mobility of Uranium During Low Temperature Alteration Processes". Unpublished Ph. D Thesis, University of Exeter, U.K. 63-98.

6. Levinson, A.A. 1974. *Introduction to Exploration Geochemistry.* Applied Publishing LTD: Maywood Illinois. pp 614.

7. Mackay, R.A. and Beer, K.E. 1952. *The Albite-Riebeckeite-Granites of Nigeria*. Geological Survey of Great Britain S. W. pp 1-25

8. McDermott, A. 1977. "Field Experiments with Exploration Model GR-101A". *Geometrics Exploranium Model GR-101A Users Manual*. pg 10.

9. OECD and IAEA. 1979. "Uranium Resources, Production and Demand". A joint Report by OECD and IAEA. 63-69.

10. STI/PUB. 2001. "Analysis of Uranium Supply to 2050". Technical Report Series, 1104: 1-7.

11. Uwah, J.E. 1984. "Investigation of Radiometric Anomalies by Nuclear and Other Methods: A Case Study of the Sokoto Basin of Nigeria". Unpublished Ph.D. Thesis, Ahmadu Bello University, Zaria.

SUGGESTED CITATION

Olugbenga, A.F. 2009. "Preliminary Investigation of some Radiometric Anomalies at Kufena Ring Complex, Zaria Kaduna State, using Gamma Ray Scintillometer". *Pacific Journal of Science and Technology.* 10(1):591-601.

Pacific Journal of Science and Technology