Application of Radiometric Surveys to Delineate between Sedimentary Terrain and Basement Complex: A case study of Sagamu and Abeokuta, South Western Nigeria

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Abstract
NaI (TI) detector crystal coupled to a Canberra series 10 plus multichannel analyser (MCA) was used to analyse the soil samples collected from Sagamu (Sedimentary terrain) and Abeokuta (Basement complex) in South Western Nigeria. The use of the soil samples is to determine the activity concentrations due to radium, thorium and potassium so as to delineate between the two terrains using radiometric survey. From the result of the activity concentrations of these radionuclide, the mean value of the activity concentrations of ^{40}k (72±48) in sedimentary terrain is higher than in ^{226}Ra (35± 20) and ^{232}Thorium (43 ±26) respectively. In the basement complex, the average value of the activity concentration of ^{40}k (80 ±46) was also higher in ^{226}Ra (44±18) and ^{232}Thorium (53 ± 25) respectively. The relatively high value recorded ^{40}k radionuclide may be attributed to the perceived variations in the environment resulting from past activities. The results shows that the activity concentration of the radionuclides is higher in basement complex than in sedimentary terrain thus, delineate between the two terrains since it is well know that in basement complex, granites contain high concentrations of uranium, thorium and potassium.
Keywords: key words: Activity concentrations, Basement complex, Radiometric survey, Sedimentary terrain, Soil samples

1. Introduction

Radiometric survey is one of the geophysical techniques often used and a useful tool in geological mapping to delineate between sedimentary terrain and basement complex of South Western Nigeria. The great global interest in the study and survey of naturally occurring radiation and environmental radioactivity had been essentially based on the importance of using the results from such studies for the assessment of public radiation exposure rates and the performance of epidemiological studies, as well as reference radiometric data relevant in studying the possible changes in environmental radioactivity due to nuclear, industrial and other human technology-related activities (UNSCEAR, 2000).

Radioactivity is the spontaneous decay or disintegration of an unstable atomic nucleus usually accompanied by the emission of radiation (Heinrich, 1985). One of the ways to achieve greater accuracy in facies delineation is by the use of radiation (alpha – α, beta-β and gamma –γ) emanating from the decay of radioactive element contained in the rock unit (Amadi et al; 2012). The most useful of these radiations in radiometric survey are gamma radiations. Gamma rays can penetrate up to 30cm of rock and several hundred metres of air, and are the only choice available for the remote sensing of terrestrial radioactivity.

Each gamma-ray photon has a discrete energy and this energy is characteristic of the source isotope. This forms, the basis of gamma-ray spectrometry. Energies of geological interest lie between 0.2 and 3 Me v which corresponds to electromagnetic wavelengths of about 3 x 10^{-12} m and a frequency of about 3 x 10^{-19} Hz (Minty, 1997).

The Nigeria land area is made of 923,768km^2 where 50% of the total surface area is underlain by basement complex and the remaining 50% by sedimentary rocks (Rahaman, 1988). There are two groups of granites in the geological setting of Nigeria and these are known as the older granites and the younger granites. The older granites are widespread and often give rise to smoothly domed hills (Inselgers). The younger granite suites which include granites, sy- enites, and rhyolites cover intensive area in plateau province and also occur as small masses (Kogbe, 1976).

The study area Ogun state (Sagamu and Abeokuta) lies on the western part of Nigeria between latitude 6^0 30’^{N} and 7^0 30’N of the equator and longitude $3^0$00’E and 6^0 30’E of the Greenwich meridian (Figure 1). The study is aimed at determine the activity concentrations of natural radioactive elements in soil samples so as to delineate between sedimentary terrain and basement complex.

2. Materials and Methods

Fifteen locations were pre-survey first in each of the sedimentary and basement terrains under investigation. At each location, soil samples of about 500g were collected to a depth of 0.5m and transferred into a polythene bag and taken to radiation laboratory, physics department, University of Ibadan for processing.

At the laboratory the soil samples were dried until there was no detectable change in the mass of the sample at 110^0C in an oven which is temperature controlled. The dried samples were grounded and pulverised into powder form. Only 200g of the dry weight soil samples were used for the analysis using a 76 x 76mm NaI (TI) detector crystal (Model No 802 series, Canberra Inc) enclosed in a graded 10cm – thick Canberra lead Shield. The detector was coupled to a Canberra series 10 plus Multichannel Analyser (MCA) (Model No. 1104) through a preamplifier using 5m connection co-axial cables.

The choice of NaI (TI) detector used in this study is as result of its modest energy resolution (Full Width at Half Maximum Height (FWHM) of about 8% at energy of 0.662 Mev (137Cs).

The soil samples were measured for a period of 10hr, after which the net area under the corresponding γ-ray peaks in the energy spectrum was used to compute the activity concentrations in the soil samples through the equation (Obed et al; 2005; and Jibri et al; 2007b):

$C\ (Bq\ Kg^{-1}) = KC_n$, - where $K = {}^{1}/_{\varepsilon}\ P\gamma\ Ms$,

C = the activity concentration of the radionuclide in the sample given in Bq Kq^{-1}

C_n = the count rate under the corresponding peak

ε = the detector efficiency at the specific γ -ray energy

Pγ = the absolute transition probability of the specific γ-ray.

Ms = the mass of the soil sample in kg.

It should be mentioned here that, the detection limit of the measuring system used in this work were 17.3 Bq Kq^{-1}, 4.2Bq Kq^{-1} and 5.1 Bq Kq^{-1} for ^{40}K, ^{226}Ra, and ^{232}Th, respectively. Values below these numbers were taken in this study as being Below the Detection Limit (BDL) of the detector. The results of the activity concentrations of the radionuclides in the soil samples measured are presented next.

3. Results and Discussions

The measured activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in the soil samples from fifteen (15) locations each in sedimentary terrain and basement complex are presented in tables 1 and 2 respectively, along with the statistical measurement uncertainties.

The error terms in the mean values in the tables are the standard deviations of the range of values across the terrains.

As could be seen from the tables, the mean activity concentrations of ^{226} Ra, ^{232}Th and ^{40}k for sedimentary terrain were 35±20, 43 ±26 and 72 ± 48 respectively. The activity concentration of ^{40}k is the highest when compared with other radionuclides. According to Jibiri et al, 2009 the relatively high value recorded ^{40}k radionuclide may be attributed to the perceived variations in the environment resulting from past activities.

In the basement terrains, the activity concentrations of the radionuclides follow the same pattern as the case in sedimentary terrain where ^{40}k is higher in value than other radionuclide. The values were; 44 ± 18, 53 ± 25 and 80 ± 46 respectively for ^{226}Ra, ^{232}Th and ^{40}k respectively. It should be noted that, in general, the activity concentrations of the radionuclides in basement complex is higher than in the sedimentary terrain.

It is well known that in basement complex, granites contain high concentrations of uranium, thorium and potassium (Lopez et al, 2004; Yang et al, 2005). The uranium and thorium are incorporated into the rocks in the crystallisation of the last magmas and residual solutions since their large ionic radii hinder them from crystallising in the early silicates (Shiva Prasad et al, 2008). This shows that, the host materials (Sand and Granites) in basement complex has a higher radiation emission than in sedimentary terrain

4. Conclusion

Interpretation of radiometric data is more similar to interpreting the results of a conventional geological survey; understanding of how radiometric survey can be applied to exploration problems requires the consideration of the geologic source of radioactivity (Hansen, 1980).

Urquhart, 1988 says that much of the uranium and thorium in igneous rock is concentrated in a few accessory minerals such as zircon, sphene and apitite. Other highly radioactive minerals, like monazite, allanite, uraninite, thorite and pyrochlore are wide spread in nature but they are very minor consistituents of rocks and are distributed erratically.

The minerals that carry uranium and thorium are generally associated with felsic intrusions -particularly with younger intrusion, they are found much less frequently in mafic rocks or in volcanics. The uranium and thorium content of rock generally increases with acidity, with the highest concentrations found in pegmatites (Grant, 1982).

Uranium is easily oxidized to a water soluble form and can be readily leached from pegmatites and granites and redeposit in sediments at large distances from the source rock while thorium has no soluble ion and therefore tends to remain with the parent rock or Transported over relatively short distances in the form of solid mineral grains (Bristow, 1979; Grasty, 1979 and Urquhart, 1988**)**.

The natural environmental radioactivity in a location depends primarily on its geological and geographical conditions. It is related to the composition of each lithologically separated area and the content of the rock from which the soil originates (Whicker, 1983; Wollenberg and Smith, 1990).

The study has provided data on the radionuclide concentrations in the soil samples of both sedimentary and basement terrain of southwestern, Nigeria. The results showed that, the activity concentrations of the radionuclides in basement complex (44 ± 18, 53 ± 25 and 80 ± 46 for ^{226}Ra, ^{232}Th and ^{40}k respectively) is higher than in the sedimentary terrain (35±20, 43 ±26 and 72 ± 48 for ^{226}Ra, ^{232}Th and ^{40}k respectively.), thus, delineate between the two terrains. This shows that, the host materials (Sand and Granites) in basement complex have a higher radiation emission than in sedimentary terrain.

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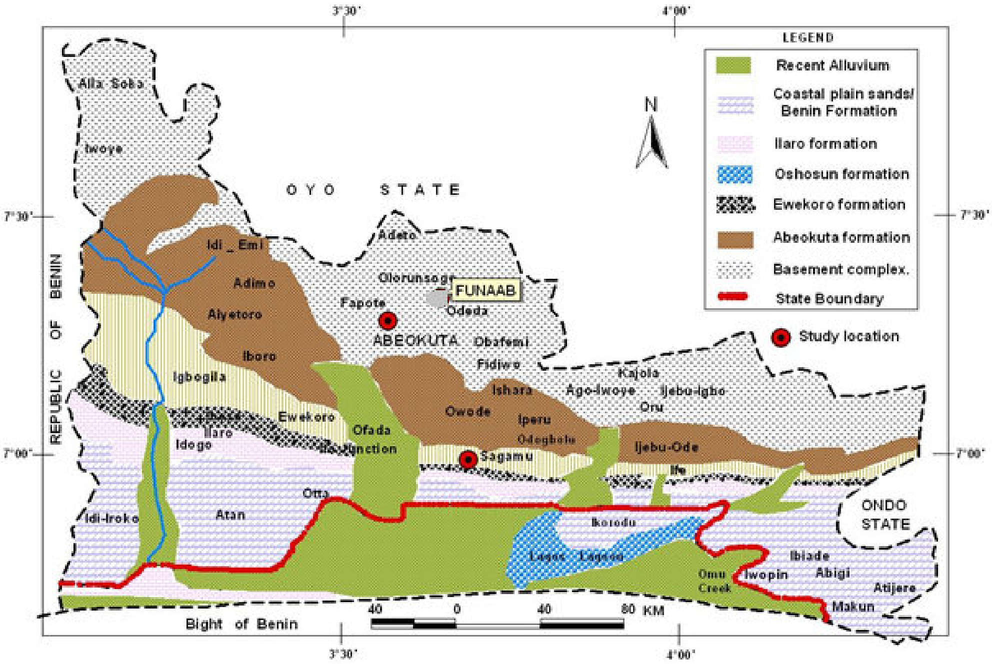

Figure 1. The geological map of Ogun State showing the study locations.

Table 1. The activity concentrations due to ^{226}Ra, ^{232}Th and ^{40}K in the soil samples from Sagamu

Soil samples	**^{226}Ra(Bq Kg^{-1})**	**^{232}Th (Bq Kg^{-1})**	**^{40}K(Bq Kg^{-1})**
1	37 ± 6	52 ± 11	80 ± 7
2	43 ± 9	37 ± 8	62 ± 11
3	41 ± 12	50 ± 13	71 ± 9
4	22 ± 7	41 ± 20	64 ± 13
5	39 ± 11	24 ± 6	52 ± 6
6	20 ± 3	33 ± 9	43 ± 10
7	17 ± 6	40 ± 11	47 ± 8
8	25 ± 10	39 ± 5	52 ± 12
9	46 ± 5	31 ± 7	83 ± 5
10	15 ± 7	20 ± 9	39 ± 8
11	32 ± 8	55 ± 14	39 ± 11
12	40 ± 12	46 ± 11	60 ± 9
13	35 ± 9	38 ± 7	53 ± 7
14	29 ± 6	30 ± 10	40 ± 5
15	24 ± 13	58 ± 14	66 ± 13
Mean	**35 ± 20**	**43 ± 26**	**72 ± 48**