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# RADIOMETRIC MAPPING OF MAJOR ROCK TYPES IN SOUTH-WESTERN NIGERIA

*By*

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***Abstract***

*The survey revealed that the lithologic character of each rock unit is a function of the amount of radioactive mineral it contained. Although each of the instrument used has its own gamma radiation values, they exhibited the same graph trend which reflected difference in gamma radiation. Based on the major rises and falls of the radioactivity graph, various formation in the area were delineated and these formations are found to correspond approximately to those on the geological map of the area produced in the conventional way. A close study of the lithologic characteristics of these formations revealed that the amount of gamma count is reflected by the radioactive mineral content of the particular formation.*

**Keywords:** Radiometric mapping, Rock types, Radioactive elements and South-western Nigeria.

## Introduction

Radioactivity was first discovered by Becquerel in 1896, shortly after Roentgen had announced the discovery of X-ray in 1895. Becquerel found that minerals containing uranium emits radiation which affects photographic emulsion in a manner similar to X-ray. One of the responsibilities of geoscientist is to map, correlate and delineate as correctly as possible different lithologies. This task, however, has not been so easy to combat owing to certain field problems arising from obscured rock units caused by deep weathering, overburden and glacial covers. Therefore, apart from areas of definite outcrop rock contact, most of the other forms of rock unit delineations are subjective (Bankole, et. al, 2006). This is because they mostly depend on personal experience and judgment of the geologist.

However, radiations (alpha-α, beta-β and gamma-□) emanating from the decay of radioactive elements are found to be of invaluable aid to geological mapping. Most useful among these are Uranium (U), Thorium (Th) and Potassium (K). The decay of these elements produces gamma rays which are useful in radiometric survey. Radioactivity causes the spontaneous change in the character of nucleus and emission of a particular radiation. It occurs in those elements with too many neutrons in their atoms which make them unstable; thus they disintegrate into daughter nuclides with an emission of energy. Uranium (U), Thorium (Th), and Potassium (K) have found wide application in mineral exploration and lithologic delineation, and this is what led to the present study.

**Location of study area**

Within the Southwestern part of Nigeria, the area of survey lies between longitudes 2°30'E and 4°30'E and latitudes 6°20'N and 7°30'N (Fig. 1). Geologically, it is underlain by both the basement complex and sedimentary formations-Abeokuta, Ewekoro, Ilaro, Imo shale, Ameki, Ijebu, Benin and alluvium as contained in Table 1.

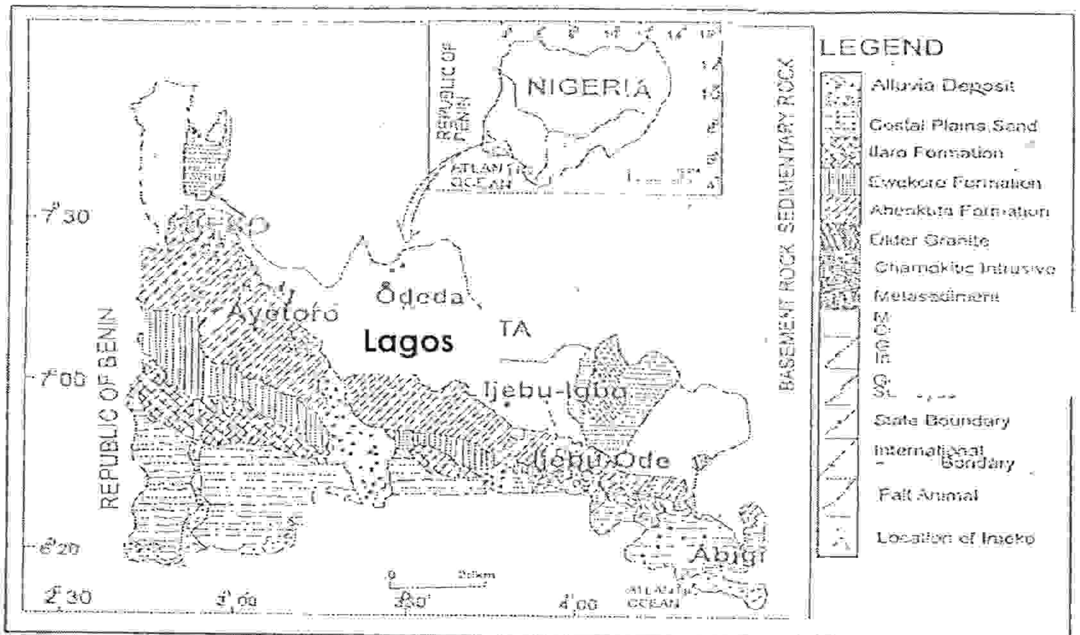


**Fig. 1: Geological Map of the Study Area.**

**Table1: Stratigraphic correlation of Dahomey Basin.**

| Age | Jones and Hockey (1964) | Adegoke and Omatsola (1981) |
|---|---|---|
| Recent | Alluvial Littoral Lagoonal Deposit. | No Equivalent found |
| Miocene Oligocene | Coastal Plain Sand | Coastal Plain Sand |
| Upper Euocene-Oligocene | Baro Formation | Ilaro Formation |
| Lower Euocene-Middle Eocene | Oshosun Formation | Oshosun Formation |
| Lower Eocene-Upper Paleocene | Akimbo Formation | Akimbo Formation |
| Paleocene | Ewekoro Formation | Ewekoro Formation |
| Mastrician | Araromi Formation | Araromi Formation |
| Turonian | Afowo Formation | Afowo Formation |
| Neocomian Albian | Ise Formation | Ise Formation |
| Precambrian | Basement Complex | Basement Complex |

**Study Objective**

The paper aimed at establishing the importance of radiations especially gamma, emanating from radioactive elements contained in rock formation to geological mapping and mineral exploration.

**Instruments and Field Methods**

Gamma radiation counting instruments used were the Gamma Ray Spectrometer Model DISA-300 (Fig. 2) and Broadband Gamma Ray Scintillometer BGS-ISL (Fig.3) was used for the study. Traverses were made across the general trend of the rock formation with a view to monitoring the changes in the gamma radiation values of these formations and subsequently delineate them. Major intersection of positive and negative gradient of arms of the radioactivity graph marks off a new formation; minor intersections are intra-formational and may be due to variation in the radioactive element content within the same formation. On this basis, radioactivity graphs delineating the various formations were prepared and comparison made with equivalent sections of the geological maps of the area traversed which were prepared in the conventional way. This enabled useful deductions and conclusions to be made on the relevance of this survey to geological mapping as well as in mineral exploration. At every location, average gamma radiation values (counts per second-cps) as reflected by the two instruments used are noted. Plots of gamma values against distance in kilometers covered in each traverse.

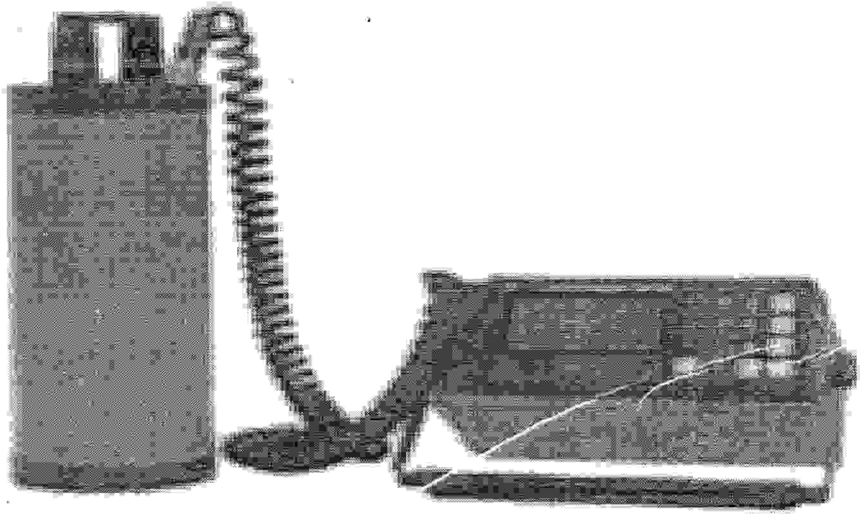

**Fig. 3** Scintillometer (Model :BGS-ISL)

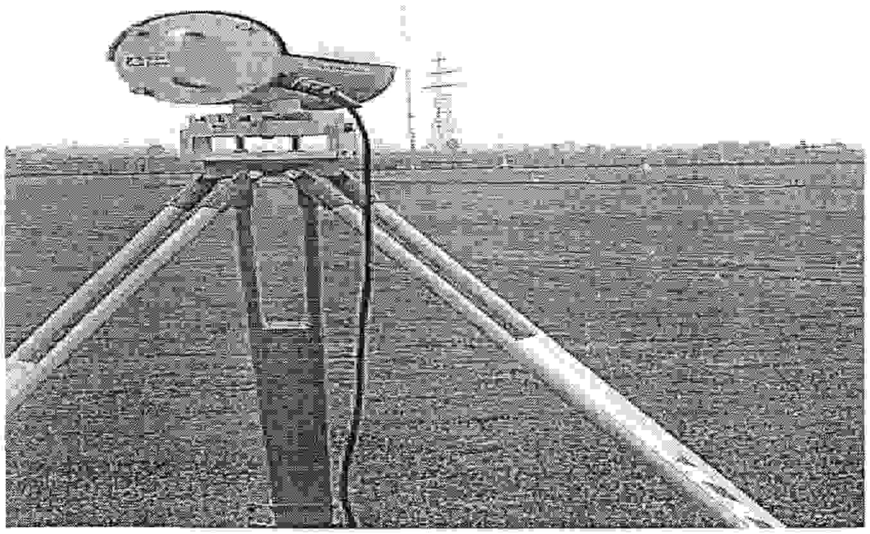

**Fig. 2** Spectrometer (Model: DISA-300)

**Occurrence of Radioactive Elements in Rocks/minerals.**

In the zone of melting, where magma rises slowly under pressure, the rise takes place by differences in the pressure between top and bottom. There is, therefore, the tendency for dissolution of crystalline material at the top and deposition at the bottom as crystalline material are more soluble at low pressure than the high pressure at the bottom (Rayment, 1965). This situation produces chemical changes in the melting; the elements with slightly larger ions and undesired charges tend to be accumulated in the residual material. Potassium (K) which has a high ionic radius remain in the liquid while other elements such as lead (Pb), cesium (S), strontium (Sr), barium (Ba), Zirconium (Zr), tantalium (Ta), fluoride (F), Chloride (Cl), carbon (C), phosphorous (P), and hydrogen (H) which do not enter the silicate mineral structure remain in solution and get deposited as radioactive elements by residual fluid of a magmatic upsurge.

## Mobility of Radioactive Elements

### Uranium

Uranium of primary mineralization in rocks occurs in the form of $U^{4+}$. On decomposition, however, of these rocks, uranium transcends to $U^{6+}$. This is relatively soluble in the zone of weathering and is available in acid medium of sulphurdized rocks, which are oxidized due to weathering and leads to highly mobile form of uranium called uranyl sulphate ($UO_2SO_4$). Uranium may also be transported in the form of hydrosalt and as complex alkaline uranium carbonates. Other form in which it is transported includes: alkaline humic compound, uranyl-bicarbonate and uranyl-tricarbonate and they are stable in carbonate rich water.

By these processes it is possible to remove uranium originally in rock from the zone of weathering. When acid water becomes neutralized, there is a formation of gelatinous compound of iron hydroxide [$Fe(OH)_2$], which absorbs uranium while with the gelatinous precipitate, uranium becomes liberated to form its own compound within mantle of waste. Infiltration deposits of uranium are associated with litho-facies such as sandstone, conglomerate, coal seams, and beds of bituminous rocks (mainly in the fissures). It is found in these rocks worldwide.

### Potassium

According to Langmuire, (1972) Potassium (K), under the joint action of water, carbon-dioxide and organic acid, is released from its rock source in the form of potassium salt. The weathering of silicates and allumino-silicates (Table 2), especially in the complex processes of hydrolysis, disintegrate potassium and its associated mineral. Feldspar (plagioclase and or orthoclase) weather easily to release potassium in solution. The potassium element is transported to the sea and later finds its way to the sedimentary environment through agents of erosion (Table 2).

### Thorium

This element belongs to the titanium group, which has no natural fissionable type, but when bombarded with neutrons it becomes uranium ($^{233}U$), which is fissionable. Generally, radioactive elements (uranium, thorium and potassium) are enriched in the residual phases of magmatic differentiation which is associated with the formation of alkaline rocks from where they are leached off and concentrated in various sedimentary units in differential settling depending on the geochemical characteristics of the environment. Deposition of clay, shale, slate, carbonate rocks and carbonaceous sediments are known to have high content of radioactive mineral (Heinrich, 1985). Ultramafic and mafic minerals including all early formed minerals such as olivine, pyroxene and amphiboles contain very low amount of radioactive minerals. This is because they crystallize before the consolidation of the late magmatic radioactive-rich deposits like uranium, thorium, titanium, apatite and magnetite.

**Table 2: Chemical Analysis (wet%) and Trace Element Contents (ppm) of rocks in the area.**

| Parameters | L-1 | L-2 | L-3 | L-4 | L-5 | L-6 | L-7 | L-8 | L-9 | L-10 | L-11 | L-12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $K_2O$ | 11.75 | 12.03 | 13.23 | 12.85 | 12.64 | 12.20 | 12.77 | 11.05 | 10.82 | 11.47 | 11.65 | 10.80 |
| $Na_2O$ | 2.21 | 2.21 | 1.85 | 2.08 | 2.47 | 2.28 | 2.36 | 2.46 | 2.94 | 2.49 | 2.27 | 2.75 |
| CaO | 0.59 | 0.62 | 0.37 | 0.46 | 0.42 | 0.63 | 0.35 | 1.14 | 1.18 | 0.81 | 0.88 | 0.59 |
| $Al_2O_3$ | 81.0 | 80.0 | 86.0 | 83.0 | 81.0 | 81.0 | 83.0 | 75.0 | 72.0 | 78.0 | 79.0 | 76.0 |
| Ab | 15.0 | 16.0 | 12.0 | 14.0 | 16.0 | 15.0 | 15.0 | 17.0 | 20.0 | 17.0 | 15.0 | 20.0 |
| An | 4.0 | 4.0 | 2.0 | 3.0 | 3.0 | 4.0 | 2.0 | 8.0 | 8.0 | 5.0 | 6.0 | 4.0 |
| Rb | 294.0 | 308.0 | 333.0 | 328.0 | 355.0 | 284.0 | 348.0 | 276.0 | 260.0 | 272.0 | 275.0 | 237.0 |
| Sr | 282.0 | 276.0 | 290.0 | 289.0 | 244.0 | 285.0 | 231.0 | 292.0 | 264.0 | 300.0 | 340.0 | 192.0 |
| Ba | 1604 | 1713 | 2126 | 1966 | 1852 | 2095 | 1581 | 2092 | 1641 | 2127 | 2273 | 1319 |
| K/Rb | 332.0 | 324.0 | 330.0 | 325.0 | 296.0 | 357.0 | 305.0 | 332.0 | 345.0 | 350.0 | 352.0 | 379.0 |
| K/Ba | 61.0 | 58.0 | 52.0 | 54.0 | 57.0 | 48.0 | 67.0 | 44.0 | 55.0 | 45.0 | 43.0 | 68.0 |
| Rb/Sr | 1.04 | 1.12 | 1.15 | 1.15 | 1.46 | 1.00 | 1.51 | 0.95 | 0.98 | 0.91 | 0.81 | 1.23 |
| Ba/Rb | 5.46 | 5.56 | 6.38 | 5.99 | 5.22 | 7.38 | 4.54 | 7.58 | 6.31 | 7.82 | 8.27 | 5.57 |
| Ba/Sr | 5.69 | 6.21 | 7.33 | 6.80 | 7.59 | 7.35 | 7.84 | 7.16 | 6.22 | 7.09 | 6.69 | 6.87 |
| Ca/Sr | 1.49 | 1.59 | 0.90 | 1.14 | 1.58 | 1.58 | 1.08 | 2.77 | 3.18 | 1.93 | 1.85 | 2.19 |

**Results and Discussion**

**1. Traverse along Lagos-Ibadan Expressway**

The gamma radiation readings were observed to be generally higher for the scintillometer than the arithmetic average of spectrometer for the same location. While the reading ranged (560-100) cps in the scintillometer, the spectrometer showed a general range of (19.75-38.88) cps. The discrepancy in readings may be attributed to perhaps the greater sensitivity of scintillometer to gamma radiations than the spectrometer. From the plots, radiation in counts per second against distance in kilometers, it can be observed that the differences in gamma radiation values notwithstanding, the radioactivity graph marked out at the various formations traversed are basically the same (Fig. 4). The four main sections in the graph pattern designated ($F_1$, $F_2$, $F_3$ and $F_4$) correspond to different rock formation (Fig. 5).

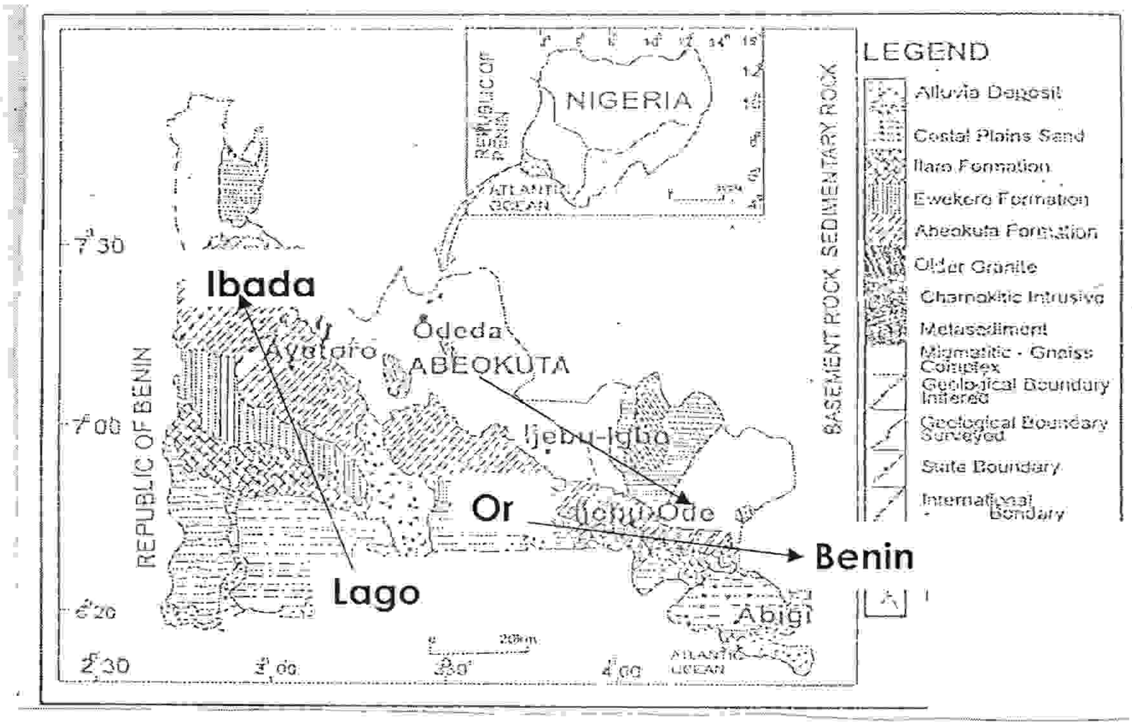


**Fig. 4: Map of the study area showing the Traverse direction.**

**$F_1$:** This shows a gamma radiation range of (65-85) cps in scintillometer and an equivalent of (25-27) cps in spectrometer. From the geological map of the area (section on traverse), this rock group is basement-fine to medium grained biotite and muscovite granite. As a granitic rock, late phase formation in magmatic differentiation, it is likely to contain some radioactive elements in their primary state. The mineralogy of the rock reflects the presence of muscovite [$KAl_2(AlSi_3)O_{10}OH_1F$) which contains much radioactive potassium (K).

**$F_2$:** This corresponds to Abeokuta Formation (Adeleye, 1978). Conventional geological map produced along Ibadan-Lagos Expressway. The lithologic character of the formation is that of variable sequences of argillaceous and sandy sediment. The range of gamma values (65-75) cps for scintillometer and (23.5-32.5) cps for spectrometer are moderately high. The intra-formational rises and falls of the radioactivity graph may be attributed to variation in rock composition. Organic matter containing argillaceous and sandy fractions are potential sites for free movement of the mobile radioactive ions but have poor adsorbing or ion-exchange capacity and as such does not fix or trap radioactive elements (Adegoke and Omatsola, 1981).

**$F_3$:** High values of gamma radiation 75-105 cps (scintillometer) and 27.5-38.5 cps (spectrometer) are noted. It reflects the highest concentration of radioactive elements in the traverse. The formation-Ewekoro, lithologically is composed of limestone and shale bodies with a lot of glauconite $K(Fe^{3+}Al_2)(SiAl)_4O_1(OH)_2$. Limestone and shale are capable of trapping mobile radioactive elements as they are known to be replete in organic matter. The presence of glauconite, which is a potassium (K) containing element, also adds to the high content of radioactive elements which has been amply reflected in the graph pattern.

**$F_4$:** The gamma values of (75-90) cps for scintillometer and (29-32) cps for spectrometer are moderately high. On the geological section, this formation is alluvium. Its moderate gamma value may be as a result of some newly deposited mobile radioactive elements but which can be leached off easily due to porosity of the alluvial deposit. The clay fractions within the alluvium would also contribute to the rise in radioactive element content.

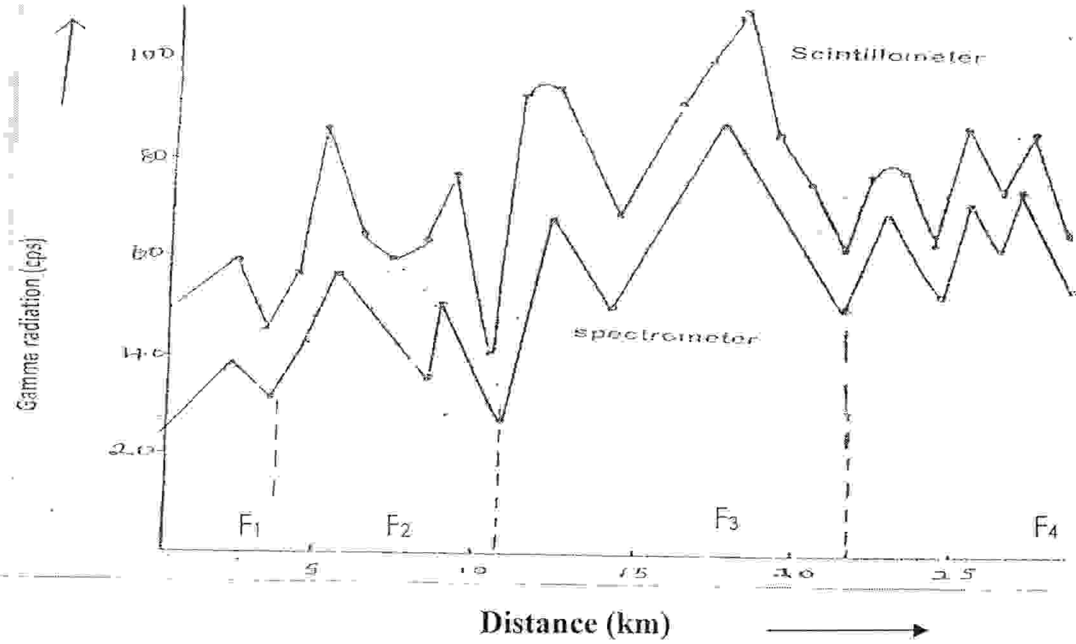


**Fig. 5: Plot of gamma radiation (cps) against distance (km). Transverse: Ibadan- Lagos expressway**

1. **Traverse along Abeokuta-Ijebuode road**

The two instruments reflect the same radioactivity graph pattern at an average range of 35-100cps for scintillometer and 9-34cps for spectrometer (Fig. 4). The three main sections in the graph pattern designated ($G_1$, $G_2$ and $G_3$) correspond to different rock formation as contained in Figure 6.

**$G_1$:** Undifferentiated gneiss complex, schist and coarse grained to porphyritic hornblende biotite granodorite. The high gamma rays must have been as a result of high content of radioactive elements in the initial sediments before metamorphism. Metamorphism has some demobilization effect on the radioactive elements but may not necessarily affect the amount of radioactivity. Hornblende, however, by its mineralogy does not contain potassium, thereby causing a downward trend in the gamma radiation (Jones and Hockey, 1964). This is also applicable to granodiorite.

**$G_2$:** This is another rock unit of the basement reflecting low values which seem to be consistent with the lithologic character of the unit. It is mainly biotite and hornblende gneiss intercalated with amphibolites. The mineral elements here are mainly mafic, known to be associated more with early differentiates of a magmatic body and subsequent devoid of most of the radioactive elements common with residual fractions.

**$G_3$:** This section of the plot shows another appreciable rise in the gamma radiation in the two graphs with (35-70) cps for scintillometer and (10-20) cps for spectrometer. This corresponds to another locality where Abeokuta formation was traversed. Its lithologic character is fertile for radioactive mineral content.

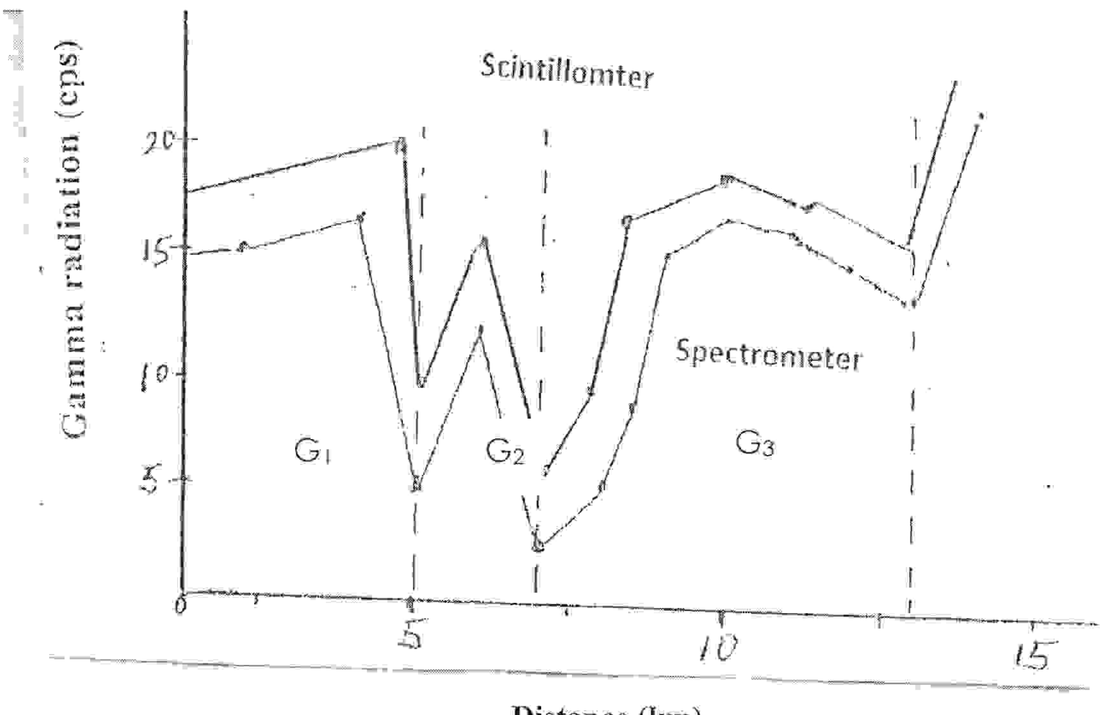


**Fig. 6: Plot of gamma radiation (cps) against distance (km). Transverse: Oru-Ijebude road**

**2. Traverse along Ore-Benin road**

It is good to note that in the traverse Ore-Benin, a distance of about 21km was covered which cut across the sedimentary/basement contact (Fig. 4). The five main sections in the graph pattern designated ($H_1$, $H_2$, $H_3$, $H_4$ and $H_5$) correspond to different rock formation as summarized in figure 7.

**$H_1$:** Both graphs reflect low gamma values of (60-70) cps and (14.5-23.5) cps for scintillometer and spectrometer respectively. On the geological map, this unit corresponds to coastal plain sands (Benin Formation) while lithologically; the formation is characterized by sands and pebbly bands with some intercalation of clay bodies. Unconsolidated pebbles and sands with no specified cementing material are not likely to contain much of mobile radioactive elements as they lack organic material except for some shale intercalations. This explains why the gamma radiation value was low in both equipments.

**$H_2$:** A high gamma reading of (70-110) cps for scintillometer and (23.5-34.5) cps for spectrometer clearly marks out the lignite formation. This formation consists of clay, shales and lignite plus some sand bodies. The presence of high organic containing materials (clay and shale) has contributed in adsorbing the radioactive minerals. Lignite is very radioactive and is made up of $^{14}C$, which decays to release gamma radiation in the energy range of (1.3-4.9) Mev and gets transformed to nitrogen ($^{14}N$).

**$H_3$:** This formation shows moderate to high gamma values (75-80) cps and (33.5-34.5) cps for scintillometer and spectrometer respectively. On the geological map, the area represents Imo shale which as its name implies is composed mainly of shale and clay. These fractions are normally replete in organic material and have high ionic exchange tendencies and thus most likely to trap mobile radioactive elements such as uranium.

**$H_4$:** Similarly, the lithologic composition of the formation speaks for its moderately high values (75-100) cps for scintillometer and (7-38) cps for spectrometer respectively. The formation is cross-stratified, false bedded sandstone, coal and shale (upper coal measure). Coal and shale in this formation are the major sources of radioactive elements (Jones, 2002).

**$H_5$:** This unit corresponds to the basement encountered near the contact (basement/sedimentary) at Ore end of the traverse which shows high gamma count of (85-99) cps and (29-33) cps for the two instruments respectively. The basement is undifferentiated and is composed of gneiss, granite, migmatite and schist. As a result, it will understandably contain some radioactive both in their primary and secondary states.

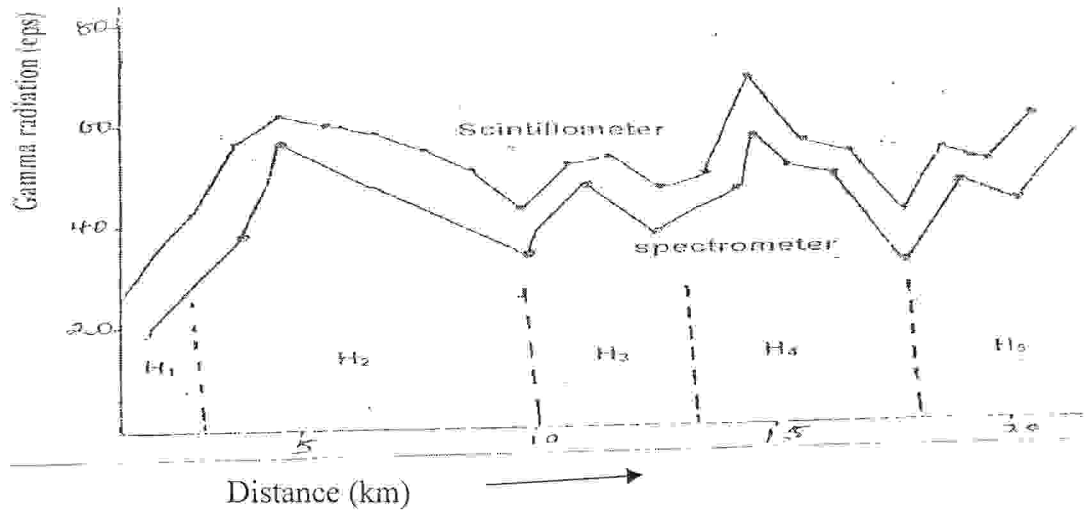


**Fig. 7: Plot of gamma radiation (cps) against distance (km). Transverse: Ore-Benin road**

## Conclusion

There is high degree of consistency in the radioactivity graph pattern of the two instruments used and subsequently in the attempt to delineate the rock formations on the basis of radioactive mineral content. Geological sections of the traverse routes have been produced to compare with the radioactivity graph and both delineate the same formation accurately. The lithologic characteristics of each formation is amply reflected by the amount of gamma radiation recorded, thus confirming the fact that lithologies as shale, clay and granite have high content of radioactive minerals. It has been ascertained that radiometric survey can provide invaluable tool in aiding rapid compilation of a geological maps and in the location of anomalies in mineral exploration.

## Recommendation

Readings taken at very shorter intervals along the traverses gave clearly radioactivity graphs; therefore it is recommended that in future survey, reading should be taken at very close range. It should be complemented by geophysical methods like magnetic so as to produce a synergic result. Due to the sensitivity of the instruments, readings should not be taken near expressway to avoid interference with cars and other metal objects as these could influence the results.

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