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Radiogenic Heat Potential Evaluation of Apomu, Southwest Nigeria: Implications for Renewable Energy improvement and exploration

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ABSTRACT
The growing world's request for clean and sustainable energy sources requires the evaluation of alternative energy potentials, which include Radiogenic Heat Production (RHP). This research work evaluates the quantity of RHP of Apomu, a geologically significant town in Southwest Nigeria, with the objective of measuring its appropriateness for renewable energy exploration. Therefore, the most common naturally occurring radioactive elements, primarily thorium concentration (Th), potassium (K) and uranium (U) were subjected to an empirical Mathematical expression over eighteen (18) major rock units. Some of the rock units include Coarse Granite Biotite (Ogm), Coarsehomblende Granite (OGh), Fine Grained biotite (Ogf), Undifferentiated Schict (Su), Carbonatceous/Slate Phyliteandmeta Siltstone (Sp), Amphibole Schist (Sa), Mylonites (aMy), Bandgneiss (bG), Granitegneiss (GG), Granuliteandgneiss, Banded Iron Formation (Bif), Biotitegranite (Ogf), Coarsehomblendegranite (Ogh), Medium to Coarse granitebiotite (Ogm), Bioitehomblendegneiss (Bgh), Pegmatite(P), Dolerite (D) and Biotitegranodiorite (Ogd). The results obtained from the mathematical expression revealed the RHP values range from 0.112 $\mu W/m^3$ to 9.746 $\mu W/m^3$ with an average value of 4.929 $\mu W/m^3$. The highest RHP value of 9.746 $\mu W/m^3$ was recorded along Dolerite (D) rock units, while the lowest value of 0.118 $\mu W/m^3$ was recorded over phylite and meta siltstone (Sp) rock outcrops. In addition, the spatial distribution of the RHP over the area reveals an even distribution of heat production with high values dominating, while the lower values were observed to be scanty in the study area. Meanwhile, the order of increasing RHP magnitude of rock units arranged is: D >Sp >Ogb >Ogh >Su >Bif > Bgh >Ogf >GG>Sa >Ogm>Ge>aMy>P. In conclusion, the RHP values obtained from these rock units are high enough to explore geothermal energy sources.

Keywords:
Apomu,
RHP,
Radiometric data,
rock units,
gamma-ray
spectrometry.

INTRODUCTION

Radiogenic heat production (RHP) is a critical geophysical process that quantifies the heat generated by the natural decay of radioactive isotopes, primarily Uranium-238 (238U), Thorium-232 (232Th), and Potassium-40 (40K), within the Earth's crust. This heat contributes to the Earth's thermal budget, influencing geothermal gradients and driving geological processes such as magmatism and metamorphism (Telford et al., 1990). In crystalline basement terrains, such as Nigeria's Precambrian Basement Complex, rocks like granite gneiss, migmatite, and granite exhibit elevated concentrations of U (4.5–13 ppm), Th (25–70 ppm), and K (2–4%), resulting in RHP values typically ranging from 0.5 to 5 $\mu W/m^3$ (Adekanmi et al., 2024). As of now, there is little or no sufficient information on the RHP pattern of Apomu southwestern Nigeria. Therefore, analyzing and interpreting radiometric data from this area is critical in order to address the existing knowledge gap. These values are crucial for assessing geothermal energy potential, an underexplored renewable energy source in Nigeria (Akingboye et al. 2021). To assess this renewable energy, Airborne radiometric surveys, using gamma-ray spectrometry, which measures gamma radiation emitted by U, Th, and K to map their concentrations across large areas. These surveys, conducted with 500 m line spacing in Nigeria, provide high-resolution data for RHP calculations using the available rock density to ensure accuracy (Ogungbemi et. al 2021). RHP values obtained is a proxy in the estimation of heat potential of an area, since regions of high values tends to reveal higher surface heat flow vice versa. This is because the decay in the radiogenic is a major contributor to crustal heating.

Geology of the Study Area

Geologically, Apomu falls within Precambrian basement complex of Nigeria which has been described by many geologists including (Obaje, 2009; Balogun 2019; Lawal et al. 2025). This area essentially falls within the migmatite gneiss complex and the Schist belt. The lithological units in the area include migmatite, gneiss, schist, and quartzite which occupy about 60% of the landmass. The gneiss includes granitegneiss, bandedgneiss, migmatitegneiss, and bandediron formation. The schist belt is generally localized to the south-western part of Nigeria is made up of Younger Meta-sediments found majorly in thecentral region of the area as shown on the geological map (Figure 1). In addition, the Ifewara faultsystem which is of the four important fault systems in Nigeria was found to have stretch throughthe study area. Studies have shown that this schist belt is generally associated with both metallicandnon-metallic minerals (Lawal, 2020).

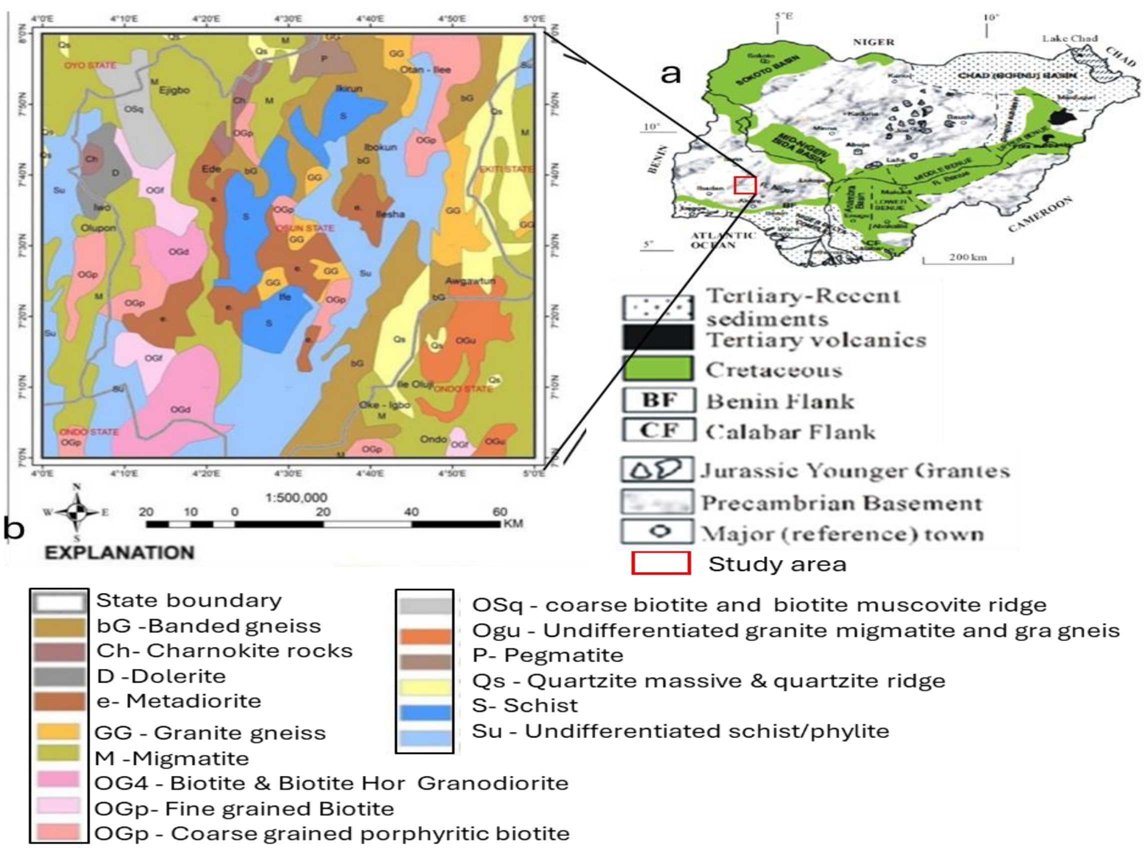

Figure 1: Map of Nigeria showing the location of the study area (Lawal et al. 2025).

MATERIALS AND METHODS

Airborne radiometric data was obtained from the Nigerian Geological Survey Agency (NGSA, 2024). Thedata were acquired between 2004 and 2010 by NGSA via an aircraft flown at 80 m height and 500 mline spacing, 80 m mean terrain clearance (NGSA, 2024). The data acquisition was jointly financed by the Federal government of Nigeria and world bank as part of thesustainable development goal for mineral exploration program. This exercise was carried out byFugro Airborne Surveys limited Johannesburg, South Africa. Corrections including background radiation resulting from aircraft and cosmicrays'contamination, variations caused by changes in the altitude of aircraft relative to the ground were performed on the data after the acquisition. Further corrections on the data include Compton scattered gamma rays in potassium and uranium energy window. In view of the above, the corrected Airborne Radiometric data provides an estimate of the apparent surface concentration of potassium (K) measured in

(%), Thorium (Th) measured in ppm and Uranium with the unitmeasuredin ppm.

Data Analysis and Interpretation

The corrected Airborne radiometric data were plotted and presented as contour maps using theOasis Montaj (Geosoft inc. 2017). The same data were subjected to qualitative and quantitativeinterpretation. For qualitative interpretation, we obtained contour maps of the surface distribution of these elements that is the Potassium (K%), equivalent Thorium (eThppm), equivalent Uranium (eU ppm) and lastly the Total-count (TC Ur). The total amount of radioactive heat production obtained through contribution by each of the radio elements (eU, eTh, and % K) was calculated by using the relation provided by Rybach (1988) as shown below:

$$\{RHP\}\ (\mu W/m^3) = 0.0952 * C_U + 0.0256 * C_{Th} + 0.0347 * C_K$$

where, C_u and, C_{Th} are the concentration of uranium, thorium radioelements which are measured in weight parts per million (ppm). Meanwhile, % K is the weight percentage of potassium radio-elements, and ρ is the average dry rock density of the rocks which are measured in g/cm^3.

RESULTS AND DISCUSSION

The plots and qualitative interpretation of airborne radioactive element is well discussed in the work of (Lawal et al. 2025). Meanwhile, Figure 2 shows the RHP plot of Apomu southwestern Nigeria.

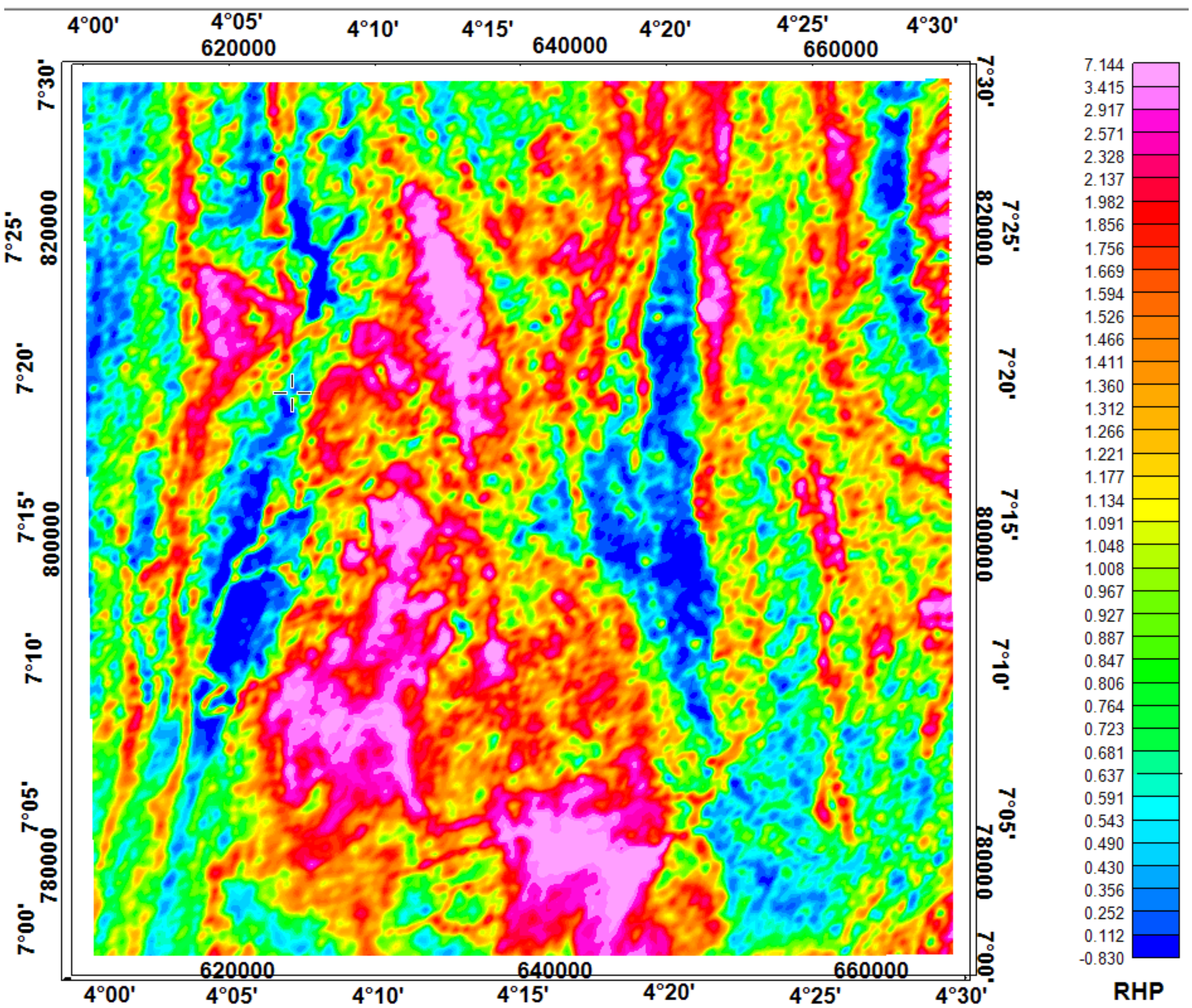

Figure 2: RHP map of the study area.

The evaluated RHP map (Figure. 2) are resultant of the number of radioactive elements (eU, eTh and K) acquired via aero radiometric survey. This figure also reveals that RHP varies directly with the various rock units. This is an indication which shows that there is a good correlation between the geological map and the RHP. The heat produced can be seen to depict variable level of radiation. Basically, there are four (4) levels of radiation in the RHP map. The high-level radiogenic heat production areas have the heat production range of 1.594 $\mu W/m^3$> 7.1 $\mu W/m^3$ (reddish to magenta in color), The radiometric high heat production zones correspond to the basements (granitic, gneissic) rocks, as well as the basic rocks outcrops of the northern and eastern parts of the area. Secondly is the moderate RHP zones to be exhibiting the RHP value of 1.091 to 1.594 $\mu W/m^3$ (greenish - yellowish in color). Thirdly are the low-level heat production areas with values ranging from 0.635 to 1.091 $\mu W/m^3$. this corresponds almost entirely with the igneous rock outcrops in the area. And lastly is the fourth level of radiogenic emission observed which is the very low-level radiation components that is represented by the light blue to dark blue-colored anomalies (> 0.112 $\mu W/m^3$ to 0.646 μ W/m^3). Moreso, the RHP values (as shown in Table 1.0) obtained across the 18 rock units shows that the order of increasing RHP magnitude of rock units arranged are: D >Sp >Ogb >Ogh >Su >Bif > Bgh >Ogf >GG>Sa >Ogm>Ge>aMy>P.

Table 1: RHP parameters of major rock units in the area.

Rock Unit	Statistical Values	K (%)	eTh (ppm)	eU (ppm)	TC (Ur)	Density value g/cm^3	RHP $\mu W/m^3$
Coarse Granite Biotite (Ogm) (1145)							
	Min	0.1	0.01	0.4	1.5	2.6	0.108722
	Max	5	34.3	7	42.9	2.6	4.468048
Coarse homblende Granite (OGh) (575)							
	Min	0.01	2.7	-0.2	3.7	2.75	0.138677
	Max	3.5	63.8	11.8	75.2	2.75	7.91571
Fine Grained biotite (Ogf) (837)							
	Min	0.01	1.1	0.9	0.2	2.7	0.308308
	Max	2.8	38.2	7.7	43.5	2.7	4.88268
Undifferentiated Schict (Su) (1291)							
	Min	0.1	0.2	0.9	0.3	2.7	0.254556
	Max	6.1	47.9	11	58.1	2.7	6.711444
Phylite and Meta Siltstone (Sp) (1411)							
	Min	0.1	0.7	0.24	0.2	2.68	0.118585
	Max	5.2	74.3	12.9	90.4	2.68	8.873802
Amphibole Schist (Sa) (1332)							
	Min	0.1	1.8	0.6	1	3.08	0.328574
	Max	3.5	31.3	6.5	37.7	3.08	4.74899
Mylonites (aMy) (944)	Min	0.16	1.9	0.9	2.4	2.8	0.391686
	Max	3.2	27.3	5.7	35	2.8	3.788064
Band gneiss (bG) (425)	Min	-0.001	-0.3	-2	1.3	2.64	-0.52302

	Max	3.2	32.3	7.4	40	2.64	4.336781
Granite gneiss (GG) (334)	Min	0.01	2.1	0.6	3.6	2.64	0.293642
	Max	4.6	29.7	9.9	40.9	2.64	4.918003
Granulite and gneiss (Ge)	Min	0.01	2	0.7	2.1	2.64	0.312016
	Max	3.5	31.5	7.5	38.7	2.64	4.335408
Banded Iron Formation (Bif) (402)							
	Min	0.1	1	0.4	2.3	3.1	0.208196
	Max	4.6	34.2	9.5	46.2	3.1	6.014
Biotite granite (Ogf) (837)	Min	0.01	1.1	0.9	0.2	2.75	0.314017
	Max	2.8	38.2	7.7	43.5	2.75	4.9731
Coarse hornblende granite (Ogh) (575)							
	Min	0.01	2.7	0.2	3.7	2.75	0.243397
	Max	3.5	63.8	11.8	75.2	2.75	7.91571
Medium to Coarse granite biotite (Ogm) (1145)							
	Min	0.1	0.01	0.4	1.5	2.65	0.110812
	Max	5	34.3	7	42.9	2.65	4.553972
Bioite homblende gneiss (Bgh) (1390)							
	Min	0.01	0.4	1.1	0.1	2.75	0.317097
	Max	2.6	45.5	9.5	52.7	2.75	5.93912
Pegmatite (P) (922)	Min	0.01	3.8	1.4	-4.6	2.8	0.646542
	Max	3.1	21.1	5.3	25.1	2.8	3.22728
Dolerite (D) (948)	Min	0.1	0.9	0.6	3.5	3	0.25092
	Max	4.1	74.1	12.7	90.5	3	9.74604
Biotite granodiorite (Ogd) (458)							
	Min	0.2	0.2	0.8	1.4	2.72	0.240013
	Max	2.2	25.6	5.6	31.2	2.72	3.440909

CONCLUSION

This research work has thrown more light into the distribution patterns of RHP across the various rock units in the Apomu, southwestern Nigeria. This spatial pattern was based on the analysis and the interpretation of airborne radiometric data of the area. The results obtained from the mathematical expression revealed the RHP values ranges from 0.112 $\mu W/m^3$ to 9.746 $\mu W/m^3$ with an average value of 4.929 $\mu W/m^3$. The highest RHP value of 9.746 $\mu W/m^3$ was recorded along Dolerite (D) rock units, while the lowest value of 0.118 $\mu W/m^3$ was recorded over phylite and meta siltstone (Sp) rock outcrops. The highest RHP values obtained from these rock units are high above the threshold value of 4.0 $\mu W/m^3$. Therefore, this area is viable for renewable energy exploration.

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